CERES BDS (BiDirectional Scan) Aqua Edition2 Data Quality Summary

Investigation:	**CERES**
Data Product:	**B**i**D**irectional **S**can (BDS)
Data Set:	**Aqua (Instruments: FM3, FM4)**
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, 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.

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.

Table of Contents

Nature of Data Product

This document discusses the **B**i**D**irectional **S**can [**BDS**] data set version **Edition2** for Aqua. 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 scene spectral 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 Aqua 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. 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 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 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. The current data set may be referred to as "CERES Aqua FM4 Edition2 BDS" and "CERES Aqua FM3 Edition2 BDS".

Processing Updates in Current Edition

Corrections implemented in the CERES Edition2 Aqua BDS and ERBE-Like products consist of:

- Corrections for on-orbit drifts in the calibration coefficients
- Corrections for on-orbit drifts in the spectral response functions

The CERES Aqua Edition1 BDS and ERBE-like data sets contained significant drifts in the spectral throughput of the FM3 and FM4 SW portion of the Total channels, as well as significant drifts in the Gains (responsivities) of both the FM3 and FM4 SW channels. These drifts are accounted for and removed in the Edition2 Data Set. Studies of the first 14-months of Edition1 BDS and ERBE-Like data products comparing FM3 and FM4 with each other as well as with onboard calibration sources, 3-channel consistency checks, and deep convective clouds have all confirmed that the SW channel gains have changed at the rate of 0.3%/yr and 0.43%/yr for the FM3 and FM4 SW channels respectively. The sign is such that the values of the FM3 and FM4 SW data products were increasing with time. The spectral throughput of the SW portion of the Total channels (i.e. <3.0 microns) changed at the rates of 0.94 and 0.57 %/yr in the FM3 and FM4 Total channels. The sign is such that the Total channels optics were transmitting more SW energy with time. Changes in the FM3 and FM4 Total channel gains were on the order of 0.2% from June 2002 through June 2003. Tables 1 and 2 present the changes made to the radiometric gains and spectral response functions to account for on-orbit changes in instrument responsivity and on-orbit changes in the sensor spectral throughput. Values used for radiometric gains and spectral response functions may be found in the daily BDS and ES8 data product files.

Table 1. On-orbit gain changes expressed as a linear drift over the time period of June 2002- June 2003

	FM3 (%/yr)	FM4 (%/yr)
Total	< 0.2	< 0.2
Window	-	-
Shortwave	0.3	0.3

Table 2. On-orbit changes in the spectral response functions expressed as a linear drift over the time period of June 2002 - June 2003

	FM3 (%/yr)	FM4 (%/yr)
SW/Total (< 3.0 microns)	0.94	0.57
LW/Total (> 3.0 microns)	-	-
Window	-	-
Shortwave	-	-

Since the CERES Daytime LW measurements are determined by differencing the Total and SW channels, the resultant daytime LW error may be correlated with the amplitude of the scenes daytime SW flux. For the Aqua Edition1 data products, both the SW and SW portion of the Total channels drifted in the same direction, offering some canceling of the associated errors in the daytime LW data products. The Edition1 FM3 Daytime LW global mean all sky LW fluxes are low by roughly 0.6% or 1.5 Wm^{-2}. The largest errors will exist for instantaneous daytime deep convective cloud LW fluxes: by June 2003 these reached a value of about 7.5 Wm^{-2}. The Aqua Edition2 BDS and ERBE-like data products reduce these errors to less than 1.0 and 2.0 Wm^{-2} respectively.

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 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 Edition2 BDS product, users should refer to the data as Aqua 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 Aqua 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 [$Wm^{-2}sr^{-1}$]	**FM3**	.079	.074	.073	.075	.082
	FM4	.081	.076	.075	.077	.084

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 [$Wm^{-2}sr^{-1}$]	**FM3**	.69	.65	.62	.63	.65
	FM4	.68	.64	.61	.62	.64

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 [$Wm^{-2}sr^{-1}$]	**FM3**	.03	.029	.029	.031	.034
	FM4	.028	.027	.027	.029	.032

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 Aqua Spacecraft is expected to perform a deep space pitchover maneuver. This maneuver will allow CERES to make final measurements of their scan dependent offsets by allowing the instruments to scan deep space. If these measurements demonstrate significant change from pre-flight values, they will be incorporated in future data product editions. An update will be posted in the Quality Summary once this maneuver is completed and the measurements analyzed.

2. The CERES SW channels have experienced significant darkening in their Spectral Response Functions below 0.8 microns. By March 2005, this darkening has reduced the average global all-sky SW flux measurements by 0.9 and 0.7 percent for FM3 and FM4 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 Aqua 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.

Document Creation Date: March 10, 2004
Modified: Jul 2005; Sep 2005
Most Recent Update: Jan 23, 2006