CERES ES8 Aqua Edition2
Data Quality Summary

ATMOSPHERIC SCIENCE DATA CENTER

Investigation:	**CERES**
Data Product:	**ERBE-like Instantaneous TOA Estimates (ES8)**
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 which has been determined by the CERES Team. This document briefly summarizes key validation results, provides cautions where users might easily misinterpret the data, provides helpful links to further information about the data product, algorithms, and accuracy, and gives information about planned data improvements, and, finally, 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 for 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.

The deep space calibration maneuvers planned for early in the Aqua mission were delayed, resulting in larger uncertainties in the CERES Aqua scan angle dependent offsets (zero-level counts) used in the level 1b BDS data product. BDS level 1b data is the input to the ES8 data product. The early unavailability of deep space scans puts a larger uncertainty on the CERES archived data products, and the BDS Aqua Edition2 archived Data Quality Summary gives an estimate of this uncertainty. Both the BDS and ES8 Aqua Edition2 Data Products use offsets determined using ground calibration data. While CERES/TRMM/Terra showed consistency of ground and in-space determined offsets of 1 digital count or better (roughly 0.5% or better) further indirect analysis as well as final deep space scans are required to confirm this level of consistency on the Aqua instruments.

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Nature of the ES8 Product

This document discusses the Aqua **E**RBE-like **S**cience Product **[ES8]** data set version **Edition2**. Additional information is in the Description/Abstract Guide. The files in this data product contain one day (24 hours) of filtered and unfiltered radiances, top-of-the-atmosphere (TOA) fluxes, and scene identification. Each radiance and its associated viewing angles are located in colatitude and longitude at a reference level of 30 km. The unfiltering algorithm produces radiances for three spectral bands for each measurement point or footprint: the longwave (LW) band measures energy emitted by the Earth's surface and atmosphere predominantly from wavelengths >5 microns, the shortwave (SW) band measures reflected sunlight primarily from wavelengths <5 microns, and the window (WN) band measures energy emitted mostly from the Earth's surface over the wavelength range from about 8 microns to about 12 microns. Radiances are converted to fluxes at the TOA for the SW and LW bands. For the WN band, only filtered and unfiltered radiances are recorded on this product.

The data are organized in time of observation. The three principal scan modes are the Fixed Azimuth Plane (FAP) mode, the Rotating Azimuth Plane (RAP) mode and the Along-Track mode. To determine CERES instrument operations on any given day, refer to the CERES Operations in Orbit. In all cases, the instrument scans across the Earth with views of space on either side which gives a full Earth view. The FAP mode produces uniform area sampling while the RAP mode produces angular sampling of the radiances.

A full list of parameters on the ES8 is contained in the CERES Data Product Catalog (PDF) and a full definition of each parameter is contained in the ES8 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 ES8" or the "CERES Aqua FM3 Edition2 ES8."

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 ES-8 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.

ES8 Edition2_Rev1

The CERES Science Team has approved a table of scaling factors which users should apply to the Edition2 ES8 parameters CERES SW filtered radiance, CERES SW unfiltered radiance, and CERES SW flux at TOA. Users should multiply each instance of these parameters 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 Aqua Edition2 Quality Summary under the Expected Reprocessing section. After application of this revision to the Edition2 ES8 product, users should refer to the data as Aqua ES8 Edition2_Rev1.

Data Accuracy Table

The ES8 products contain estimates of instantaneous filtered radiance, unfiltered radiance, TOA flux, and scene type. The nature of an estimate is that it is uncertain with a bias error and a random error about the bias which can be measured by its standard deviation. Thus, an understanding of the uncertainty in an instantaneous estimate must consider both biases and standard deviations. Often the uncertainty is given in terms of the RMS error which includes both the bias and standard deviation.

Uncertainties in the filtered radiances are given in Table 1. The Total (TOT) channel errors are given separately for night and day since daytime TOT contains both shortwave and longwave radiance while nighttime contains only longwave. The filtered radiances are determined from the instrument counts by multiplying by a gain. If this gain is in error, then the filtered radiances appear to be biased. The measurements are also subject to random measurement noise. All of these errors are combined and given as RMS errors.

Table 1: Uncertainty of Filtered Radiances

Instrument Channel	Typical Value[a] Wm^{-2}sr^{-1}	Systematic Bias Error (Accuracy)			Mean Zero Random Error Standard Deviation (Precision)		Instantaneous RMS error
		Instrument R [b] 1 std dev	Ground Cal. Gain error[c] 3 std dev	Instrument Drift over 6 months	Instrument R [b] 3 std dev	Instrument Noise[d] 1 std dev	
SW	45	1.0%	1.0%	0%	1%	0.3%	0.45%
TOT-day	125	0.5%	0.5%	0%	1%	0.1%	0.19%
TOT-night	70	0.5%	0.1%	0%	0.5%	0.1%	0.11%
WN	4.6[e]	0.3 Wm^{-2}sr^{-1}	1.0%[f]	0%	-	0.5%	1.0%

a. January 12, 1998, TRMM
b. Lee et al., *J. Atmos. Oceanic Technol*, **13**, 1996
c. Estimated from validation studies
d. Determined from space view
e. Wm^{-2}sr^{-1}µm^{-1}
f. See the CERES BDS Aqua Edition2 Quality Summary

Uncertainties in the unfiltered radiances are given in Table 2. The unfiltered radiances are linearly related to the filtered radiances by coefficients which are denoted "Spectral Correction Coefficients" (SCC). These are mean coefficients and introduce random error. The nighttime unfiltered LW radiance is determined from the TOT filtered channel radiance at night. The daytime longwave, however, is derived from the TOT, SW and WN filtered radiances.

Table 2: Uncertainty of Unfiltered Radiances

Spectral Band	Typical Value[a] Wm^{-2}sr^{-1}	Spectral Correction Bias Error	Spectral Correction Random Error 1 std dev	Instantaneous RMS error
SW	60	0	0.4%	0.6%
LW-day	85	0	0.1%	0.2%
LW-night	80	0	0.1%	0.15%
WN	6.4[b]	0	0.6%	1%

a. January 12, 1998, TRMM
b. Wm^{-2}sr^{-1}µm^{-1}

Uncertainties in the TOA fluxes are given in Table 3. The fluxes are derived by multiplying radiance by π and dividing by an anisotropic factor from the Angular Distribution Models (ADM). These ADMs are mean models and introduce random error which is the dominant error for flux.

Table 3: Uncertainty of TOA Flux

Spectral Band	Typical Value[a] Wm^{-2}	ADM Bias Error[b]	ADM Random Error[c] std dev	Instantaneous RMS error
SW	210	1.0%	12%	12.1%
LW-day	265	0.5%	5%	5.0%
LW-night	250	0.5%	5%	5.0%
a. January 12, 1998, TRMM b. Suttles, et al., *J. Appl. Meteor.*, **31**, 1992 c. Wielicki, et al, *Bull. Amer. Meteorol. Soc.*, **76**, 1995				

Differences Between CERES and the ERBE Scanner

1. The resolution of CERES-Aqua is 20 km at nadir, and the resolution of ERBE-ERBS is 40 km at nadir so that the surface area observed from ERBS is 4 times larger than the area observed from CERES-Aqua.
2. The nominal scan mode for ERBE was crosstrack to provide good area coverage. CERES has three scan modes. The Fixed Azimuth Plane (FAP) scan mode is similar to the ERBE scan mode. The Rotating Azimuth Plane (RAP) scan mode is used by CERES to provide angular coverage to construct Angular Distribution Models. The along-track scan mode is used for validation of CERES instantaneous fluxes.
3. The longwave channel on ERBE was replaced by an 8 to 12 micron window channel on CERES.
4. The data rate on ERBE was 30 measurements per second. The data rate on CERES is 100 measurements per second.
5. The ERBE S8 data product was about 36 MB in size. The CERES ES8 data product is about 480 MB.
6. ERBS has an orbital inclination of 57°. Aqua is in a 1:30 p.m. sun-synchronous orbit.
7. ES8 Edition 2 uses a different unfiltering algorithm (Loeb et al., 2000) than ERBE.

Cautions When Using Data

There are several cautions the CERES Team notes regarding the use of the CERES Aqua Edition2 ES8 data:

- 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.

- Users are responsible for applying revisions as noted in the section entitled "User Applied Revisions to Current Edition".

- CERES-Aqua is observing more clear sky than ERBE due in part to the difference in footprint size. The resolution of CERES-Aqua is 20 km at nadir and the resolution of ERBE-ERBS is 40 km at nadir so that the surface area observed by ERBS is 4 times larger than the area observed by CERES-Aqua.
- The ERBE scene identification algorithm (Maximum Likelihood Estimator, MLE) in conjunction with the ERBE angular distribution models (ADMs) are known to erroneously produce albedo growth from nadir to the limb. The ERBE ADMs are probably insufficiently limb-darkened in longwave and insufficiently limb-brightened in shortwave. The CERES-Aqua fluxes also have these biases with viewing zenith angle.
- Some applications of the ES8 data will need to make the distinction between Fixed Azimuth Plane (FAP), Rotating Azimuth Plane (RAP) and along-track scan data. All 3 scan modes can occur on the same day so that the data parameter "Scanner Operation Flag Word" (see ES8 Collection Guide) must be examined for each data record to properly identify the scan mode for each footprint.
- Data users are strongly urged to examine the flags for each footprint in order to determine if the data for that footprint are good or bad.

Validation Study Results

The validity of the filtered radiances, unfiltered radiances, TOA fluxes, and identified scene types has been examined with various validation studies and quality checks.

Unfiltered Radiances:

The unfiltered radiances are linear functions of the filtered radiances where the coefficients are the Spectral Correction Coefficients (SCC). The SCCs are based on the spectral response of the instrument channel, S^i_λ, where λ is wavelength and i = SW, TOT, WN for shortwave, total, and window channel, respectively. The S^i_λ has been measured as part of the instrument calibration and characterization. The SCCs are based on a database of spectral radiances from typical surfaces, such as ocean, land, desert, snow, and cloud. The methodology used in producing Aqua Edition2 unfiltered radiances is the same as that used in the CERES TRMM Edition2 ES8 product and is outlined in Loeb et al., (2000). This method differs from that used on ERBE. To unfilter SW radiances, the ERBE unfiltering algorithm used a theoretical ratio

between unfiltered and filtered radiances defined at various angles in overcast and cloud-free conditions over ocean, land, desert and snow. Interpolation between these theoretical ratios was used to determine coefficients under partly and mostly cloudy conditions. The ERBE approach has been shown to produce large errors when applied to CERES due to the differences between the CERES and ERBE spectral response functions (see Loeb et al., 2000).

Theory:

To estimate uncertainties in instantaneous unfiltered radiances for each channel, the unfiltering algorithm was used to estimate radiances from approximately 10,000 theoretical test cases representative of clear and cloudy conditions over ocean, land and snow. The test calculations were determined from MODTRAN + DISORT radiative transfer calculations at high spectral resolution and represent a wide range of cases.

Errors in instantaneous SW unfiltered radiances from both FM3 and FM4 were found to be <0.5% (relative). By comparison, uncertainties in PFM instantaneous unfiltered SW radiances were generally <1%. The reduction in error was particularly marked for clear oceanic scenes because the FM3 and FM4 spectral response functions are flatter than PFM at wavelengths between 0.3-0.4 microns.

In contrast, the theoretical results revealed slightly larger uncertainties in unfiltered LW radiances from FM3 and FM4 compared to PFM. For most scenes, FM3 and FM4 uncertainties remain less than 0.4% (relative) compared to 0.2% for PFM. However, for extremely cold clouds (e.g. deep convective clouds), uncertainties in FM3 and FM4 unfiltered radiances can reach 1% for both daytime and nighttime conditions.

In the WN channel, all three instruments showed very small uncertainties in unfiltered radiances (<0.2%) for all scenes.

References

1. Currey, C. and Green, R., 1998,"Validation of the CERES shortwave measurements over desert and cloud scenes", *Am. Meteor. Soc.*, 10th conference on atmospheric radiation, 567-570.

2. Haeffelin, M., B. Wielicki, J.P. Duvel, K. Priestley, M. Viollier, 2000: "Inter-calibration of CERES and ScaRaB Earth radiation budget datasets using temporally and spatially collocated radiance measurements". *Geophysical Research Letters*, (in press).

3. Loeb, N.G., K.J. Priestley, D.P. Kratz, E.B. Geier, R.N. Green, B.A. Wielicki, P. O'R. Hinton, and S.K. Nolan, 2000: Determination of unfiltered radiances from the Clouds and the Earth's Radiant Energy System (CERES) instrument. *J. Appl. Meteor.* (in press).

4. 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.

Expected Reprocessing

The CERES Team expects to reprocess the ERBE S8 data product for ERBS, NOAA-9, NOAA-10, and the ES8 data product for TRMM in the future. The purpose of the reprocessing is to generate a consistent, long-term climate record, where advances in the data calibration and processing will be incorporated to remove former errors. The major contribution to reprocessing will be an improved set of Angular Distribution Models (ADMs) based on CERES data and the MLE as the scene identifier. Other improvements include more accurate scanner offsets for NOAA-9 and NOAA-10, correction of the low daytime longwave flux for NOAA-9, drift corrections, and a possible resolution correction for CERES so that the CERES and ERBE footprints will be similar in size.

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.
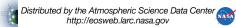
When data from the Langley Data Center are used in a publication, **we request the following acknowledgment be included:**

"These data were obtained from the Atmospheric Science Data Center at NASA Langley Research Center."

The 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 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 <u>User and Data Services</u> staff at the Atmospheric Science Data

Center.

Document Creation Date: March 10, 2004
Modification History: Jul 2005; Sep 2005; Dec 2008
Most Recent Modification: December 11, 2008