CERES ES8 TRMM-PFM Edition2
Data Quality Summary

Investigation:	**CERES**
Data Product:	**ERBE-like Instantaneous TOA Estimates (ES8)**
Data Set:	**TRMM**
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, 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.

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 quality of the CERES ES8 data is comparable to the quality of the ERBS S8 data of instantaneous radiances, fluxes, and scene types. Generally, radiance uncertainties are at the 1% level for ERBS and the 0.5% level for CERES. Some differences between CERES-TRMM and ERBE-ERBS are: the field of view resolution, the spectral response of the instruments, and the tropical-only coverage of TRMM.

Edition 2 significantly improves the quality of the unfiltered radiances compared to Edition 1. Subsequent to release of ES8 Edition 1, it was revealed that the unfiltering technique (basically the same algorithm used on ERBE) is not the best choice for CERES due to the differences between the CERES and ERBE spectral response functions. In the Edition 2 version of the ES8, this has been corrected by using a new unfiltering algorithm outlined in Loeb et al, "Determination of Unfiltered Radiances from the Clouds and the Earth's Radiant Energy System (CERES) Instrument", *J. Appl. Meteor.* [submitted 2000]. Also, updated spectral response functions were used in determining the unfiltering coefficients. Otherwise, Edition 2 ES8s use the same algorithms as was used in ES8 Edition 1 and ERBE (e.g. for determination of filtered radiances, scene identification and radiance-to-flux conversion etc.). We recommend that new users of the ES8 product use the Edition 2 version. For those who have already been using ES8 Edition 1, we provide results of comparisons between the two versions in the section on Validation Study Results.

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Nature of the ES8 Product

This document discusses the **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 principle scan modes are the Fixed Azimuth Plane (FAP) mode, the Rotating Azimuth Plane (RAP) mode and the Along-Track mode. 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. This data set may be referred to as "CERES TRMM Edition2 ES8."

Data Accuracy Table

The ES8 contains 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 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. There is no statistical evidence that the instrument gains are drifting. However, if there is a drift, it is less than 0.1% for the SW channel and less than 0.2% for the TOT and WN channels over the first 8 months of TRMM operation. 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

		Systematic Bias Error (Accuracy)			**Mean zero Random Error Std (Precision)**		**Instan'ous RMS error**
Instrument Channel	**Typical Value[a] $Wm^{-2}sr^{-1}$**	**Instrument Requirements[b] 1 std dev**	**Ground Cal. Gain error[c] 3 std dev**	**Instrument Drift over 8 months**	**Instrument Requirements[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 $Wm^{-2}sr^{-1}$	0.6%[f]	0%	-	0.5%	0.54%

a. January 12, 1998
b. Lee, et al., *J. Atmos. Oceanic Technol*, **13**, 1996
c. Estimated from validation studies
d. Determined from space view
e. $Wm^{-2}sr^{-1}\mu m^{-1}$
f. See BDS 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**	**Instan'ous 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	0.1%	0.55%

a. January 12, 1998
b. $Wm^{-2}sr^{-1}\mu m^{-1}$

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	Instan'ous 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
b. Suttles, et al., *J. Appl. Meteor.*, **31**, 1992
c. Wielicki, et al, *Bull. Amer. Meteorol. Soc.*, **76**, 1995

Differences Between CERES and ERBE

1. The resolution of CERES-TRMM is 10 km at nadir, and the resolution of ERBE-ERBS is 40 km at nadir so that the surface area observed from ERBS is 16 times larger than the area observed from TRMM.
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 for Angular Distribution Models construction. 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 had an orbital inclination of 57°. TRMM is restricted to the tropics with an orbital inclination of 35°.
7. ES8 Edition 2 uses a different unfiltering algorithm (Loeb et al., 2000) than either ES8 Edition 1 or ERBE.

Cautions When Using Data

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

1. TRMM is observing more clear sky than ERBE due in part to the difference in footprint size. The resolution of CERES-TRMM is 10 km at nadir and the resolution of ERBE-ERBS is 40 km at nadir so that the surface area observed by ERBS is 16 times larger than the area observed by TRMM. For the time period of January through July in the tropics (±20° latitude), ERBS observed about 17% clear sky and TRMM observed about 28% clear sky. ERBS also observed about 17% overcast and TRMM observed about 16% overcast. It is not fully understood why the overcast for TRMM decreased instead of increasing like clear sky. Overall, the cloud fraction was 46% for ERBS and 40% for TRMM.
2. 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 TRMM fluxes also have these biases with viewing zenith angle.
3. The strong 1998 El Niño occurred during the first few months of TRMM ES8 data acquisition and has had an influence on those results. The scene identification algorithm operates with a priori climatological data which is probably inadequate for the El Niño period of increased ocean temperatures. The increased temperature of the tropics will be interpreted as less cloud and will introduce errors in the inversion from radiance to flux.
4. 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. In general, the TRMM scan mode has been one day of RAP scanning followed by two days of FAP scanning. Also, every 15th day is along-track scanning. 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.
5. 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. The validation of the filtered radiances is discussed in the BDS Quality Summary.

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. Edition 1 uses the same spectral radiance database (except for clear ocean) and spectral correction algorithm as was used on ERBE to determine unfiltered radiances. To unfilter SW radiances, the ERBE unfiltering algorithm uses 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 is used to determine coefficients under partly and mostly cloudy conditions.

Validation studies have revealed that significant errors occur when the ERBE unfiltering approach is applied to CERES, particularly over clear ocean. For example, the ERBE spectral correction algorithm over ocean overestimates unfiltered SW radiance for large aerosol optical depths and underestimates the SW radiance for small aerosol optical depths. The net effect is likely to cause an overestimate of aerosol radiative forcing. The cause for this error is due to differences in the CERES and ERBE spectral response functions. CERES uses silver mirrors, which offer a more uniform spectral response from 0.4 micron to 1.0 micron than the ERBE aluminum mirrors, but are less responsive below 0.4 microns. In the Edition 2 version of the ES8, these weaknesses have been removed by using a new unfiltering technique (Loeb et al, 2000). The new method accounts for potential nonlinearities and nonzero intercepts in the filtered-unfiltered radiance relationship. The Edition 2 unfiltering algorithm also uses the most current CERES spectral response functions and a significantly improved spectral radiance database based on high-resolution MODTRAN+DISORT radiative transfer model calculations. We recommend that first-time users of the ES8 product use the Edition 2 version.

LW and WN radiances were found to be less sensitive to which unfiltering technique is used. A regression of the filtered radiances for the WN and TOT channels at night was performed empirically and theoretically with the two regression curves agreeing. The theoretical filtered radiances required knowledge of the S_λ^{WN} and $S_\lambda^{LW/TOT}$, where LW/TOT is the longwave part of the total channel, so that agreement validated the two spectral response functions. In addition, SCCs for the WN channel were validated with line-by-line radiative transfer calculations.

Since the ES8 results are ERBE-like, one validation study sought to compare the CERES-TRMM radiances to the historical ERBE-ERBS radiances from a decade earlier. This was done by averaging radiances over the tropics (±20° latitude) and comparing the unfiltered radiance means for three months (June, July and August), stratified by viewing geometry. Tables 4, 5 and 6 compare relative differences in unfiltered SW (Table 4), LW daytime (Table 5) and LW nighttime (Table 6) radiances between CERES Editions 1 and 2, and between CERES Edition 2 and ERBS. In the second column of each table, a typical equivalent flux value is provided for reference. The next two columns show relative differences between CERES Editions 1 and 2, and CERES Edition 2 and ERBS relative differences at the intrinsic resolution of each instrument (10-km for CERES-TRMM; 40-km for ERBS). To reduce the influence of differences in footprint size between CERES and ERBS, a sensitivity test was also performed whereby the CERES footprint was spatially averaged to ~40-km at nadir, consistent with ERBS. This comparison is shown in the fifth column of each table. Finally, the last column shows results when the Loeb et al. (2000) unfiltering technique is applied to **both** CERES and ERBS ("ERBS (mod)" refers to a modified version of ERBS).

SW radiance relative differences between CERES-TRMM ES8 Editions 1 and 2 show the largest changes over clear and partly cloudy ocean. The Edition 2 values are lower than those from Edition 1 by ~4-6%. Comparisons between CERES Edition 2 and ERBS SW radiances demonstrate the large sensitivity in CERES ES8 clear ocean radiances on footprint size. At full resolution, CERES Edition 2 radiances are lower than ERBS values by ~7.5%. When footprint size is accounted for, this difference drops to only 1.3%. This drastic change in the CERES-ERBE difference with footprint size occurs because larger footprints identified as clear under the MLE technique suffer from greater cloud contamination than smaller footprints. That is, since there is a greater likelihood of encountering undetected sub-resolution cloud when the footprint size is large, it becomes much more difficult to unambiguously identify cloud-free footprints. Consequently, CERES clear-sky SW radiances tend towards ERBE clear sky values when footprint size differences between the two instruments are removed. Not surprisingly, CERES footprint size has a much smaller influence on SW reflectances over brighter surfaces such as clear land and desert than it does over clear ocean. When both ERBS and CERES data are unfiltered using the same technique (i.e., based on Loeb et al., 2000), relative differences show much less dependence on scene type. For the most homogeneous scenes (e.g., clear ocean, clear land, clear desert, overcast, deep convective clouds), the relative difference ranges from between ~-4.7% to ~-3.4%. The all-sky relative differences (last row) are different from those for the individual scene types because of differences in the CERES and ERBS populations in these datasets. The ~-4% difference in SW reflectance between CERES and ERBS for individual scene types is surprisingly large. Since this difference shows very little sensitivity to scene type (i.e. when ERBS and CERES radiances are unfiltered using the same technique), the cause is likely not due to the unfiltering method. A more likely cause is calibration differences.

The largest difference between CERES Edition 1 and 2 daytime LW radiances (Table 5) occurs for overcast conditions, with Edition 2 radiances being lower by ~2%. Nighttime differences (Table 6) are generally < 0.5%. Differences between Edition 1 and 2 WN radiances are much smaller; Edition 2 unfiltered WN radiances are larger than those in Edition 1 by ~0.25%. Comparing CERES Edition 2 with ERBS, Table 5 shows that CERES Edition 2 daytime LW radiances are within ~0.5% of ERBS values over clear ocean, clear land and clear desert, but deviate more from ERBS as cloud cover increases. This tendency is likely due to a known bias in the ERBE spectral response function in the shortwave portion of the TOT channel (Green and Avis, 1996). This same bias is the likely reason why the all-sky daytime difference between CERES-TRMM and ERBS is ~0.75-1%, whereas at night the all-sky difference is closer to ~2%.

Another validation study sought to compare the CERES-TRMM Tropical Mean (TM) LW radiances to the historical ERBE-ERBS radiances. The most direct comparison is to restrict the TM to longwave radiance at night over an ocean background for all cloud conditions. This TM was selected to minimize the diurnal effect. Moreover, the data were restricted to nadir to eliminate angular variations. The monthly TM for ERBS was found to be fairly stable with a monthly standard deviation of 0.5% over the 60 months of ERBS data. The TRMM TM from January to August 1998 was compared to the ERBS TM and found to be higher by about 2.2%. Some of this difference was definitely caused by El Niño. However, by August 1998 El Niño had considerably subsided and the TRMM TM was still 1.7% higher than the ERBS TM. This finding does not necessarily invalidate the CERES longwave radiance at night. The difference could lie with the ERBS radiances or possibly changing climate conditions.

The only direct tie between the ERBE and CERES radiances is the ERBS wide field-of-view (WFOV) non-scanning radiometer that has been operational from 1984 through August 1998 and is still operational. Preliminary results seem to support the TM findings that longwave radiance at night is higher for TRMM than for ERBS. The WFOV results also imply that the longwave in the tropics has increased over the decade.

Table 4: Relative Difference (%) in Unfiltered SW Radiance for June, July and August

(CERES results are from 1998; ERBS results are between 1985 and 1989)

Scene Type	Typical Flux (Diurnal Avg) (W m^{-2})	Full-Resolution CERES		Reduced CERES Resolution	
		Ed2-Ed1 (%)	Ed2-ERBS (%)	Ed2-ERBS (%)	Ed2-ERBS (mod) (%)
Clear Ocean	40	-3.77	-7.50	-1.30	-3.40
Clear Land	65	1.18	-6.40	-4.70	-3.40
Clear Desert	95	0.48	-6.20	-4.60	-4.70
Clear L-O Mix	55	-1.41	-8.80	-2.50	-4.00
Partly Cloudy Ocean	65	-5.72	-0.81	5.14	4.79
Partly Cloudy Land/Desert	90	0.94	0.19	2.48	1.94
Partly Cloudy L-O Mix	80	-2.74	0.46	2.60	0.80
Mostly Cloudy Ocean	120	-1.69	1.27	-2.10	-3.99
Mostly Cloudy Land/Desert	145	0.90	3.74	1.26	-0.26
Mostly Cloudy L-O Mix	130	-0.17	1.55	-1.84	-4.28
Overcast	180	1.16	2.20	-1.00	-3.60
Deep Convective	245	0.9	-1.7	-1.7	-4.6
All Scenes	95	-0.61	-0.80	-0.80	-2.40

Table 5: Relative Difference (%) in Daytime Unfiltered LW Radiance for June, July and August (CERES results are from 1998; ERBS results are between 1985 and 1989)

Scene Type	Typical Flux (W m^{-2})	Full-Resolution CERES		Reduced CERES Resolution	
		Ed2-Ed1 (%)	Ed2-ERBS (%)	Ed2-ERBS (%)	Ed2-ERBS (mod) (%)
Clear Ocean	288	-0.16	-0.05	0.05	-0.02
Clear Land	297	-0.29	0.41	0.51	-0.23
Clear Desert	304	-0.15	0.11	-0.04	-0.23
Clear L-O Mix	290	-0.24	0.54	0.76	0.73
Partly Cloudy Ocean	275	-0.64	0.18	0.18	0.08
Partly Cloudy Land/Desert	269	-0.58	-0.05	-0.14	-0.38
Partly Cloudy L-O Mix	272	-0.73	0.27	-0.07	-0.11
Mostly Cloudy Ocean	243	-1.26	0.37	-1.27	-1.28
Mostly Cloudy Land/Desert	234	-1.24	-0.13	-0.76	-0.81
Mostly Cloudy L-O Mix	237	-1.27	-0.29	-1.34	-1.26
Overcast	164	-2.17	-2.04	-1.44	-1.03
All Scenes	259	-0.7	0.96	0.82	0.77

Table 6: Relative Difference (%) in Nighttime Unfiltered LW Radiance for June, July and August (CERES results are from 1998; ERBS results are between 1985 and 1989)

Scene Type	Typical Flux (W m^{-2})	Full-Resolution CERES		Reduced CERES Resolution	
		Ed2-Ed1 (%)	Ed2-ERBS (%)	Ed2-ERBS (%)	Ed2-ERBS (mod) (%)
Clear Ocean	292	0.18	0.36	0.26	0.11
Clear Land	279	0.22	1.22	1.11	0.97
Clear Desert	275	0.21	1.09	0.65	0.51
Clear L-O Mix	289	0.18	0.61	0.46	0.29
Partly Cloudy	275	0.14	0.42	0.40	0.20

Ocean					
Partly Cloudy Land/Desert	255	0.20	0.30	-0.04	-0.21
Partly Cloudy L-O Mix	268	0.16	0.45	0.31	0.09
Mostly Cloudy Ocean	243	0.10	0.04	-0.31	-0.60
Mostly Cloudy Land/Desert	223	0.18	0.06	-0.14	-0.34
Mostly Cloudy L-O Mix	233	0.14	0.14	-0.08	-0.37
Overcast	172	0.38	-0.98	-0.95	-0.57
All Scenes	255	0.18	2.01	2.05	1.82

Instrument Offsets

The Tropical Mean has also been used to validate the 660 individual scanner position offsets for each measurement channel. These offsets were determined prior to launch and re-determined after launch with "pitch-up" data that scanned space. There was little change between the ground and space offsets. In addition to determining the TM at nadir, the TM was determined at all 660 scan positions. These results showed: (1) there was no change in offsets from January 1998 to July 1998, and (2) there was no change in offsets between RAP and FAP.

Instrument Gains

The Tropical Mean has also been used to check the consistency between the shortwave, total, and window radiances. This test is frequently referred to as the "three channel intercomparison". Both the daytime and nighttime nadir TM were determined for longwave, and the Day-Night (DN) difference was determined. The nighttime TM was derived from the TOT, and the daytime TM was derived from the SW and TOT. The DN difference was also determined from the ERBS longwave channel which has no shortwave component and is insensitive to calibration. We have taken the ERBS DN difference as our reference. The difference between these two DN quantities can reveal potential errors in either the SW or SW/TOT channels. Results from this analysis showed that the CERES SW/TOT may be high by 0.2% or the SW is low by 0.2%. These differences are not statistically significant.

Another approach to the "three channel intercomparison" showed similar results. In general, the regression of TOT on WN is very uncertain for different scene types. However, deep convective clouds radiate like a cold blackbody and allow for an accurate regression. In other words, we can accurately determine the broadband longwave radiance from the WN channel for deep convective clouds. Thus, we can determine two instantaneous daytime broadband longwave radiances. The first is from the WN. The second is from the TOT and SW. Since this is an instantaneous difference, we can develop a scatter plot of longwave difference versus shortwave radiance. We would not expect the longwave difference to vary with shortwave. Results from this analysis indicate that either the CERES-TRMM SW/TOT is high by 0.1% or the SW gain is low by 0.1%. Again, these small differences are not statistically significant.

In summary, both the Tropical Mean DN and the Deep Convective Cloud studies suggest that the CERES channels are consistent at the 0.1-0.2% level.

Flux at TOA

The largest source of error for instantaneous single field of view TOA fluxes is the conversion of radiance to flux using the ERBE Angular Distribution Models. This ES8 ERBE-Like data product uses the same analysis procedure as ERBE and is expected to have similar uncertainties to those found for ERBE. The uncertainty values in Table 3 use the results of prior ERBE error analysis studies to predict this uncertainty for TRMM ERBE-Like data. The ERBE instantaneous uncertainty was determined for time and space-matched orbital crossings of NOAA-9 and ERBS spacecraft. The two spacecraft viewed each region from a wide variety of viewing angles, and uncertainty was determined using the differences in derived fluxes over two years of orbital crossings. Uncertainties are largest for SW fluxes.

There are also biases in the correction of radiance to flux which have been identified in the ERBE fluxes: a 10% relative change in SW flux from nadir to 70° viewing zenith angle. For monthly mean regional fluxes, however, observations cover a complete range of viewing zenith angles (for ERBE and for CERES on TRMM). Regional monthly mean flux errors (1 sigma) caused by anisotropy were found to be less than 6 Wm^{-2} for SW fluxes and less than 3 Wm^{-2} for LW fluxes. Global mean biases (ERBE - Reference) due to this error source were found to be about 1.1 Wm^{-2} for SW and 0.8 Wm^{-2} for LW. CERES will be able to improve the uncertainty analysis of these ERBE-Like results, but not until additional data are obtained.

For simultaneous uncertainty estimation, orbital crossings of TRMM, EOS-AM (Terra) and/or EOS-PM (Aqua) will be required. Terra was launched on December 18, 1999. For bias errors (regional, zonal and global) additional CERES Rotating Azimuth Plane (RAP) data are required. These data allow direct integration of fluxes over very large ensembles of radiance observations at all viewing angles and relative azimuth angles, followed by a comparison to fluxes derived for the same data using the ERBE ADMs. TRMM will allow this test to be conducted over all solar zenith angles, but it is estimated that roughly 2 to 3 years of TRMM data will be required for statistical significance of this test. Finally, a partial test of the ADM accuracy has been carried out by the ES-4 and ES-9 ERBE-Like data products. The normal operation of CERES on TRMM is for 1-day of RAP data (all viewing zeniths and azimuths sampled, but poor spatial sampling) followed by two days of crosstrack scanning (limited viewing azimuth angles but optimal spatial sampling). Six month CERES ERBE-Like average fluxes have been derived using crosstrack data alone (2 days out of 3) versus use of all data (crosstrack and RAP scanning). This test represents a minimum ADM bias error as represented by the difference in 6-month average fluxes derived for different sets of viewing azimuth angle conditions (crosstrack versus RAP). For the 6-month averages, regional 1 sigma (combined versus crosstrack only) for total sky fluxes was 2 Wm^{-2} for SW and 1 Wm^{-2} for LW. Clear-sky regional fluxes differed by a 1 sigma of 0.5 Wm^{-2} for SW and LW. Global mean biases were less than 0.1 Wm^{-2} for SW and LW flux, for total sky and clear-sky conditions. SW fluxes for crosstrack versus RAP scanning were also composited for each of 10 solar zenith angle bins (every tenth in cosine of the solar zenith angle). For all solar zenith angle bins, crosstrack and RAP fluxes agreed to better than 1.0% for all scenes, and better than 0.5% for 90% for the scene type/solar zenith angle conditions.

Scene Identification

The CERES ERBE-Like product uses the same Maximum Likelihood Estimate (MLE) method used by ERBE to select one of 12 scene classes. The 12 classes include 5 clear classes (less than 5% cloud cover over ocean, land, snow, desert, land-ocean mix) as well as 3 partly-cloudy classes (5-50% cloud cover over ocean, land or desert, land-ocean mix), 3 mostly-cloudy classes (50-95% cloud cover over ocean, land or desert, land-ocean mix), and 1 overcast class. Both spectral correction and ADMs are selected based on these 12 ERBE scene classes. These 12 ERBE scene classes were based on the Nimbus 7 NCLE cloud fraction algorithm (Stowe et al., Jour. Climate, 1988, p. 445) and were used to develop the ERBE ADMs using the Nimbus 7 ERB broadband scanning radiometer. The ERBE MLE scene identification is designed to statistically mimic the NCLE cloud algorithm without explicit use of a cloud imager since an imager was unavailable on the ERBS spacecraft. Validation of the ERBE MLE scene identification using Nimbus 7 ERB broadband radiance data and comparing to the NCLE cloud fraction values, gave 1 sigma differences of MLE and NCLE regional monthly mean cloud fraction of about 0.12 (Suttles et al., Jour. Appl. Met., 1992, p. 784). Global average frequency of occurrence of clear sky for the NCLE and MLE methods agreed within 0.014, and overcast frequency of occurrence agreed within 0.046. Because the NCLE cloud products were produced on a 180 km grid, while the Nimbus 7 ERB broadband radiance field of view varied with scan angle from 90 km at nadir to 250 km near the limb, instantaneous matched field-of-view comparisons of MLE and NCLE results were not possible.

Instantaneous ERBE and CERES field of views have been matched for ERBE/NOAA-9 with AVHRR and for CERES/TRMM with VIRS. Pixel level cloud fraction retrievals were performed with the new CERES cloud retrieval algorithm still undergoing validation. Since both the cloud algorithm and the VIRS calibration are still preliminary, these "validations" of the MLE scene identification must be considered very preliminary. In addition, the CERES cloud algorithm is both more capable and different from the early NCLE algorithm that the MLE reproduces. In that sense, the comparison with the CERES cloud algorithm is thought to be an upper bound on MLE scene identification errors: it includes both MLE errors as well as large differences between the NCLE and more advanced cloud retrieval algorithms and imager data currently available. With those caveats in mind, the imager-determined cloudy and clear pixels have been mapped with the CERES and ERBE point spread functions to obtain a direct comparison of MLE and cloud imager scene identification. These have been matched for all observations from 35N to 35S latitude, for viewing zenith angles less than 45° (near the limit for VIRS), and for orbit conditions with roughly similar solar zenith angles (50° average). NOAA-9 data was analyzed for June 20, 1986, and TRMM data was analyzed for June 2, 1998. At the individual field of view level, the MLE daytime cloud fraction class agreed with the cloud imager determination in roughly 60% of the cases for NOAA-9 and 50% for TRMM. One scene-class cloud fraction errors occurred 36% of the time for NOAA-9 and 43% for TRMM. The remaining cases were 2 scene class errors, with no significant number of 3 class-errors. Daytime clear-sky fields of view (cloud fraction < 5%) were in agreement between the imager and MLE in 55% of the cases for ERBE/AVHRR and in 68% of the cases for CERES/VIRS.

The most remarkable difference between the CERES and ERBE MLE scene statistics is the large difference in clear-sky frequency of occurrence. CERES-TRMM is observing more clear sky than ERBE due in part to the difference in footprint size. The resolution of TRMM is 10 km at nadir and the resolution of ERBS is 40 km at nadir (ERBE-NOAA-9 is 50 km at nadir) so that the surface area observed by ERBS is 16 times larger than the area observed by TRMM. For the time period of January through July, ~17% of ERBS footprints and ~28% of TRMM footprints are classified as clear-sky. ERBS also observed about 17% overcast and TRMM observed about 16% overcast. It is not fully understood why the overcast for TRMM decreased instead of increasing like clear sky. Overall the cloud fraction was 46% for ERBS and 40% for TRMM. The change in clear-sky, overcast and cloud fraction was negligible from Edition1 to Edition2. Work is underway to determine a new set of ERBE-Like ADMs using the VIRS cloud imager to improve on the NCLE cloud data, and the CERES Rotating Azimuth Plane scanner data to improve on the Nimbus 7 ERB scanner data. These new ADMs, with a new MLE, are planned for use in later reprocessing of both the original ERBE data as well as the CERES ERBE-Like product described here. This should allow significant improvements in the scene identification and TOA flux accuracy over the existing data products.

Quality Assurances

There are a number of quality checks which are listed below.

1. The LW flux is rejected if it is outside the range 50 to 450 Wm^{-2}. About 0.00% of the LW fluxes are rejected.
2. The SW flux is rejected if albedo is outside the range 0.02 to 1.00. About 0.06% of the SW fluxes are rejected.
3. The LW and SW flux is rejected if viewing zenith is greater than 70°. About 8.5% of the flux is rejected.
4. The SW flux is rejected if anisotropy from the ADM is greater than 2.0. About 0.68% of the SW fluxes are rejected.
5. The unfiltered radiances and fluxes for SW and LW are rejected if the MLE identified scene is more that 8 sigma from the expected a priori scene. About 0.01% of the scenes are rejected.
6. Filtered radiances flagged "bad" are not used. About 0.3% of the SW radiances, 0.4% of the TOT radiances, and 0.2% of the WN radiances are flagged "bad".

Expected Reprocessing

The CERES Team expects to reprocess the S8 data product for ERBS, NOAA-9, NOAA-10, and the ES8 data product for TRMM. 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 will be 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 removemajor errors and to verify the quality and accuracy of this 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 Langley DAAC data are used in a publication, **we request the following acknowledgment be included:**

> "These data were obtained from the NASA Langley Research Center EOSDIS Distributed Active Archive 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 NASA Langley DAAC User and Data Services.

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