CERES ES9 TRMM-PFM Edition2 Data Quality Summary

Investigation:	**CERES**
Data Product:	**ERBE-like Monthly Regional Averages (ES9)**
Data Set:	**TRMM**
Data Set Version:	**Edition2**

The purpose of this document is to inform users of the best current understanding of the accuracy of this CERES data product, to briefly summarize key validation results, to provide cautions where users might easily misinterpret the data, to provide helpful links to further information about the data product, algorithms, and accuracy, to give information about planned data improvements, and finally to register users of this data product so that we can automate the process of keeping users informed of new validation results, cautions, or improved data sets that become available in the future.

This document is a high-level summary and represents the minimum information that all scientific users of this data product should be familiar with. We strongly suggest that users re-check this document for the latest status before publication of any scientific papers using this data product: this would apply to both authors and reviewers of such research papers.

The quality of the CERES TRMM ES9 data is comparable to the quality of the ERBE ERBS single-satellite S9 data in terms of instantaneous gridded and monthly mean fluxes and scene identification. The major differences between CERES/TRMM and ERBE/ERBS are the field of view resolution, the spectral response of the instruments, the inclusion of rotating scanner plane data in the CERES product, and the tropical-only coverage of CERES/TRMM.

Edition 2 significantly improves the quality of the unfiltered radiances compared to Edition 1. Subsequent to release of ES9 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 ES9, 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 ES9s use the same algorithms as was used in ES9 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 ES9 product use the Edition 2 version. For those who have already been using ES9 Edition 1, we provide results of comparisons between the two versions in the section on Validation Study Results.

Table of Contents

Nature of the ES9 Product

This document discusses the **E**RBE-Like **S**cience Product **[ES9]** data set version **Edition2**. Additional information is in the Description/Abstract Guide. The CERES ES9 data product contains the "ERBE-like" temporally and spatially averaged shortwave (SW) and longwave (LW) top-of-the-atmosphere (TOA) fluxes derived from one month of CERES data from the Tropical Rainfall Measuring Mission (TRMM) spacecraft. Instantaneous TOA fluxes from the ES8 product have been spatially averaged on the same 2.5° equal-angle grid used by the Earth Radiation Budget Experiment (ERBE). Temporal interpolation algorithms identical to those used by ERBE have been applied to produce daily, monthly-hourly, and monthly mean fluxes from the instantaneous gridded data. The ES9 files contain both the temporally averaged and the instantaneous gridded mean values of TOA total-sky LW, total-sky SW, clear-sky LW, and clear-sky SW flux, total-sky albedo and clear-sky albedo for each 2.5° region observed during the month.

For more detailed information regarding this product, consult the ES9 entry in the CERES Data Products Catalog (PDF) and the CERES ES9 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 ES9."

Data Accuracy Table

Errors from Temporal Interpolation and Spatial Averaging

<table>
<tr><th rowspan="3"></th><th colspan="4">Mean Global Bias (Wm^{-2})</th><th colspan="4">Mean Regional 1σ (Wm^{-2})</th></tr>
<tr><th colspan="2">Monthly</th><th colspan="2">Seasonal</th><th colspan="2">Monthly</th><th colspan="2">Seasonal</th></tr>
<tr><th>LW</th><th>SW</th><th>LW</th><th>SW</th><th>LW</th><th>SW</th><th>LW</th><th>SW</th></tr>
<tr><td>All Latitudes 45°N - 40°S</td><td>±2 (0.8%)</td><td>±3 (3%)</td><td>±0.5 (0.2%)</td><td>±2.5 (3%)</td><td>2-5 (<2%)</td><td>8-11 (<12%)</td><td>< 2 (<1%)</td><td>< 6 (<7%)</td></tr>
<tr><td>Tropics 20°N - 20°S</td><td>±1.5 (0.6%)</td><td>±3 (3%)</td><td>±0.4 (0.2%)</td><td>±2.5 (3%)</td><td>< 3 (1.2%)</td><td>< 8.5 (<9%)</td><td>< 1.6 (<0.6%)</td><td>< 5 (<6%)</td></tr>
<tr><td>Extratropical 45° > |Lat| > 20°</td><td>±3 (1.2%)</td><td>±3 (3%)</td><td>±0.8 (0.3%)</td><td>±2.5 (3%)</td><td>< 6 (<2%)</td><td>< 13 (<14%)</td><td>< 2 (<1%)</td><td>< 6 (<7%)</td></tr>
<tr><td>Science Requirement</td><td>2 - 5</td><td>2 - 5</td><td>2 - 5</td><td>2 - 5</td><td>10</td><td>10</td><td>10</td><td>10</td></tr>
</table>

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 by ERBS is 16 times larger than the area observed by TRMM.
2. The nominal scan mode for ERBE was crosstrack to provide good area coverage. TRMM has two scan modes. The Fixed Azimuth Plane scan mode is similar to ERBE. The Rotating Azimuth Plane (RAP) scan mode was added to TRMM to provide angular coverage for Angular Distribution Models construction.
3. The TRMM orbit is in a low inclination (35°) orbit that precesses through all local times in 46 days. The ERBS had an inclination of 57° and a precessionary period of 72 days.
4. The longwave channel on ERBE was replaced by an 8 to 12 µm window channel on TRMM.
5. The data rate on ERBS was 30 measurements per second. The data rate on CERES is 100 measurements per second.
6. The ERBE ERBS S9 data product is a binary file of about 75 MB. The CERES TRMM ES9 product is an HDF file of about 72 MB.
7. Edition 2 uses a different unfiltering algorithm than either Edition 1 or ERBE (Loeb et al., 2000).

Cautions When Using Data

There are several cautions the CERES Team notes regarding the use of the ES9 TRMM Edition2 data:

1. CERES 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 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 August, ~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 as for clear sky. Overall the cloud fraction was 46% for ERBS and 40% for TRMM.
2. The ERBE scene identification algorithm (MLE) in conjunction with the ERBE angular distribution models (ADM) 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 angle.
3. The spectral response of the CERES shortwave and total channels differs from that on ERBE at wavelengths below 1 micron. CERES uses silver mirrors, which offer much more uniform spectral response from 0.4 µm to 100 µm than the ERBE aluminum mirrors, but are less responsive below 0.4 µm. A new spectral unfiltering algorithm has been developed and applied to the CERES data. As a result, the CERES radiances are less sensitive to spectral correction for land, desert, and cloudy scenes. The greatest impact of this change is on SW fluxes, particularly for clear and partly cloudy ocean scenes. Edition 2 clear-sky fluxes are lower than Edition 1 for clear ocean scenes and slightly higher for land and desert scenes. Overall, Edition 2 CERES clear-sky SW fluxes are 5-6% lower than ERBE ERBS fluxes for all scene types.
4. The TRMM spacecraft is in a 46-day precessing 35° orbit that is designed to provide good coverage of the tropics. For regions poleward of 20°N and 20°S, the temporal sampling patterns are very different from ERBS. In general, extratropical regions are viewed in daytime only during part of the month and nighttime during the remainder. The typical ERBE sampling pattern of alternating day and night observations only occurs in the tropics with TRMM. Users should be aware that this temporal sampling can cause:
    - Large regional bias errors due to not sampling all local times during a month. These errors can be reduced by a factor of 2 by using seasonal means instead of monthly means.
    - Large errors in the modeling of diurnal variations of flux, particularly for extratropical land and desert regions.

- Insufficient coverage for calculating global means since there are no data poleward of ±45°.

5. During 1998, the CERES TRMM instrument operated in a standard mode of 2 days of crosstrack scanning followed by 1 day of rotating azimuth plane (RAP) scanning. Both the crosstrack and RAP data have been used in the computation of CERES monthly mean fluxes. ERBE data were exclusively crosstrack. The scanning mode used to produce instantaneous gridded means on the ES9 can be identified by checking the value of the viewing zenith angle which will be set to the CERES fill value for RAP data.
6. The Earth may have real variations in longwave and shortwave radiation properties between the ERBE time period and the CERES TRMM time period. The major factors that we can note are:
   - The substantial and widespread increase in ocean temperature due to the strong 1998 El Niño event that lies outside the range of conditions encountered in the ERBE time period
   - Systematic changes in tropospheric water vapor between the 1998 El Niño period and the ERBE period may have an influence on LW fluxes
   - Errors in scene identification due to the use of climatological values for LW cloud thresholds that are inadequate for strong El Niño events. Increased temperatures in the tropics will be interpreted as less cloud which will introduce errors in the inversion from radiance to flux.
   - The possible darkening of some deserts owing to increased rainfall early in 1998, again owing to El Niño
   - The potential changes in radiation over the tropics due to smoke from fires in exceptionally dry forests, where the smoke may be confused with clouds

Validation Study Results

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

Pre-Launch

1. The CERES ERBE-like operational code has been tested for consistency with the historical ERBE algorithm. The CERES code was run using ERBE data as input. Monthly mean SW and LW fluxes have been calculated that reproduce ERBE values to better than 0.1%.
2. An error analysis of spatial averaging and temporal interpolation errors has been performed using one month of 1-hourly, 4-km GOES data. In summary:
   - **Spatial errors** have been computed using simulated CERES footprints constructed by convolving the GOES pixels with the CERES point spread function. These footprints can be averaged on a grid and compared with regional averages of the GOES pixels. Currently, results are only available for the CERES 1.0° grid. For crosstrack data, the rms SW and LW flux spatial gridding errors are 10.1 Wm^{-2} (5%) and 2.3 Wm^{-2} (1%) respectively, with no bias error for either. Errors for RAP data are twice as large with SW errors of 23.1 Wm^{-2} and and LW errors of 5.6 Wm^{-2}. Currently, the best estimate for instantaneous gridding error for the 2.5° ERBE-like grid is given by Stowe et al., (J. of Atmos. & Ocean. Tech, 1994). For CERES-like footprints, Stowe et al. calculated crosstrack errors of ~8.5 Wm^{-2} and ~1.3 Wm^{-2} for SW and LW, respectively.
   - **Temporal errors** were calculated by temporally sampling GOES data and comparing monthly means computed from these data with means from the complete time series. SW and LW rms monthly mean errors are <11 Wm^{-2} (<12%) and <5 Wm^{-2} (<2%), respectively. Bias errors for LW are < 0.5Wm^{-2}. For SW, mean biases can be ±3 Wm^{-2} depending on the particular TRMM sampling pattern for the month. The effects of the spatial gridding errors on monthly mean errors are negligible in the LW and only increase monthly SW rms errors by ~0.5 Wm^{-2}.

Post-Launch

1. The CERES ERBE-like data have been compared with ERBS non-scanner data for verification of calibration. Tropical monthly mean ocean total-sky LW fluxes have been averaged for all available months of ERBS scanner (1/85 - 12/89), ERBS non-scanner (1/85 - 2/98), SCARAB scanner (3/94 - 2/95), and CERES scanner (1/98 - 2/98) data. Scanner and non-scanner differences for each of the 3 scanners agree to < 1%. In addition, instantaneous CERES ERBE-like fluxes have been compared with ERBS non-scanner data. Comparisons using data from January through August 1998 have demonstrated agreement to within 0.1% for both SW flux, 0.5% for nighttime LW flux, and 2.5% for daytime LW flux.
2. Directional models of the variation of albedo with solar zenith angle (SZA) have been constructed using CERES TRMM and ERBE ERBS data for each of the 12 ERBE scene types. Comparisons of these models reveal no significant differences.
3. Six months of instantaneous rotating azimuth plane (RAP) and crosstrack fluxes have been averaged as a function of SZA and scene type. These fluxes agree to <1% in all cases with no statistically significant biases. Seasonally averaged regional fluxes computed from crosstrack data alone and combined RAP and crosstrack data also show no systematic biases.
4. The first eight months of CERES ERBE-like data have been compared with the historical ERBE ERBS scanner data from 1985-1989. The emphasis of this study has been on comparisons of tropical mean fluxes (defined as the average of all regions between 20°N and 20°S) in order to minimize temporal sampling differences.

The main results include:

- **Total-sky LW flux -** CERES LW fluxes are 3.5-8.8 Wm^{-2} (1.5-3.5%) higher than ERBE. The difference maximizes in February, which is also the maximum of the 1998 El Niño event. The difference is minimized in August when El Niño has essentially disappeared. As explained above, a corresponding increse in total-sky LW flux from ERBE (1985-1989) to 1998 is also seen in the ERBS non-scanner data.
- **Clear-sky LW flux -** The CERES clear-sky LW fluxes are 1-3. Wm^{-2} (0.2-1.0)% higher than ERBE. This difference also maximizes in February and minimizes in August. The differences have been shown to be consistent with variations in sea surface temperature and atmospheric humidity associated with El Niño.
- **Total-sky SW flux -** The difference between CERES and the 5-year mean ERBE data varies between -0.6 and -5.0 Wm^{-2} (-0.6 and

-5%). However, the 2σ bound for the month-to-month temporal sampling variability of the total-sky SW tropical mean for this time period is 5%. Seasonal (3-month) means of SW flux reduce the impact of temporal sampling to a 2σ bound of 2.5%. The CERES SW flux tropical seasonal means are lower than ERBE ERBS by 3-4% which implies that there may be a real difference between ERBE and CERES SW fluxes.

- **Clear-sky SW flux -** In Edition 1, the difference between CERES and ERBE in clear-sky SW flux varies with geographical scene type. The changes in CERES spectral unfiltering have resulted in a more constant bias: CERES fluxes are on the average 5.6%, 5.3%, and 6.1% lower than ERBE for ocean, land and desert regions, respectively. The clear ocean difference is reduced to ~4% when the CERES spatial resolution is reduced to simulate the ERBS field of view. The land and desert differences are reduced only slightly by changing the spatial resolution.
- **Scene identification -** In general, CERES classifies more footprints as clear than ERBE. This difference is also greatest in February with CERES classifying 33% of the observations as clear, while ERBE classifies only 20% as clear. The difference in July is decreased to 22% vs. 16%. Of the remaining difference, about 2% can be attributed to the smaller CERES footprint size.

Expected Reprocessing

The CERES team expects to reprocess the S9 data product for ERBS, NOAA-9, NOAA-10, and the ES9 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 contributions to reprocessing will be an improved set of Angular Distribution Models 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 CERES and ERBS 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 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.

Document Creation Date: June 22, 2000
Modification History: Dec 2000 (non-science), Aug 2001 (non-science); Dec 2001
Most Recent Modification: December 12, 2001