Clouds and the Earth's Radiant Energy System (CERES)

Algorithm Theoretical Basis Document

ERBE-like Averaging to Monthly TOA Fluxes

(Subsystem 3.0)

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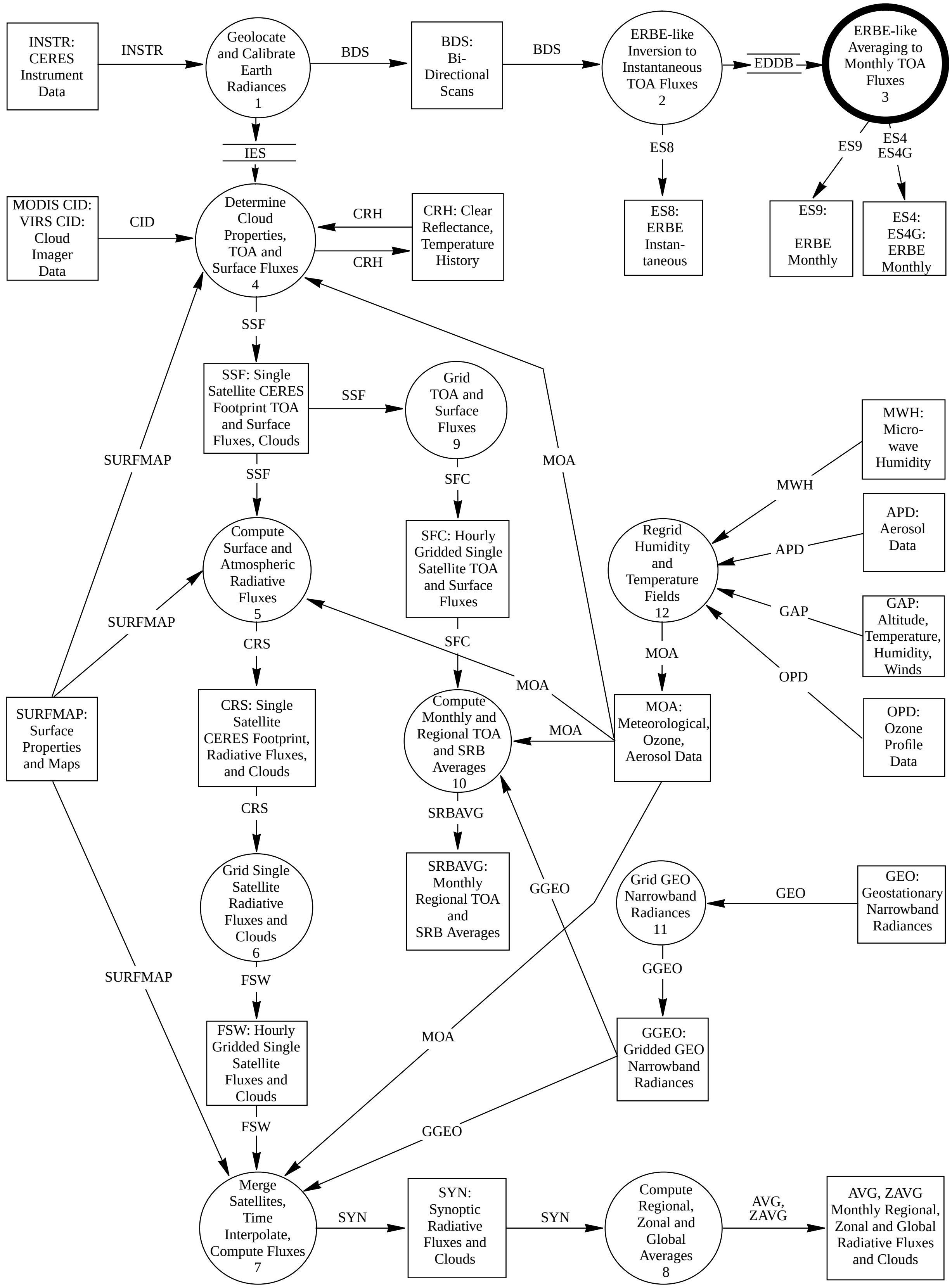
CERES Top Level Data Flow Diagram



Abstract

This subsystem describes methods to temporally interpolate CERES measurements to compute ERBE-like averages of top-of-atmosphere (TOA) radiative parameters. CERES observations of shortwave (SW) and longwave (LW) flux are time-averaged using a data interpolation method similar to that employed by the Earth Radiation Budget Experiment (ERBE). The averaging process produces daily, monthly-hourly, and monthly means of TOA SW and LW flux on regional, zonal, and global spatial scales. Separate calculations are performed for clear-sky and total-sky fluxes.

3.0. ERBE-like Averaging to Monthly TOA Fluxes

3.1. Introduction

The satellites that carry the CERES instrument do not provide continuous spatial and temporal coverage of the Earth's entire surface. Historically, the sparse distribution of satellite measurements is the most critical factor in temporal averaging of radiation data from regional to global scales (Brooks et al. 1986). Because a satellite does not view all portions of the Earth at all times, temporal modeling of the diurnal variability of the Earth's radiation field is required to recover daily or monthly averaged radiative parameters. A clear understanding of the Earth's radiative behavior demands realistic models of diurnal variations that depend on the surface type and cloud cover and accurately describe the solar zenith angle dependence of albedo and longwave exitance.

A major emphasis of radiation budget research is on the monitoring and analysis of long-term variations in the Earth's climate. This can only be accomplished using stable, long-term global data sets. In order to fulfill this research need, CERES will produce an ERBE-like product to provide a data set processed in a manner consistent with the earlier experiment (see Brooks et al. 1986).

3.2. Input

The chief input to the ERBE-like monthly time-space averaging (TSA) subsystem is the stream of CERES SW and LW TOA flux observations. Included with each measurement is necessary information such as satellite viewing geometry, the latitude and longitude of the observation, and the underlying geographic scene type. In addition, cloud amount is estimated for each pixel in the observed area. See appendix A for tables describing the input data products. Additional input data include TOA albedo angular distribution models (ADM's) and solar declination data.

3.3. Output

The TSA process produces daily, monthly-hourly, and monthly means of TOA SW and LW flux on regional, zonal, and global spatial scales. Separate calculations are performed for clear-sky and total-sky fluxes. Daily SW clear-sky fluxes are provided only for days with clear-sky measurements; daily clear-sky LW over land regions is not provided. See Appendix B for tables describing the output data products.

3.4. Summary of Processes

One month of data is sorted and averaged into the standard ERBE 2.5° latitude $\times$ 2.5° longitude grid. All data within each grid box are sorted and averaged in 1-hour increments (hour boxes).

Total-sky TOA LW flux is estimated for all hours during the month by interpolating between those hours containing observations. Linear interpolation is used over oceans, while a half-sine curve fit is applied over land and desert regions based on studies by Brooks and Minnis (1984). Monthly and monthly-hourly means are then computed using the combination of observed and interpolated values.

Clear-sky TOA LW flux is calculated in the same manner as total-sky TOA LW in oceanic regions. However, over land regions, a different technique is used to compensate for the effects of under-sampling. Hours with clear-sky LW observations are averaged over the month for each local hour. A single half-sine curve is fitted to this monthly composited data, and the monthly-hourly means from this fit are averaged to produce monthly means.

Monthly mean total-sky and clear-sky TOA SW fluxes are produced in a manner similar to total-sky TOA LW flux. For all days with at least one SW observation, a value of SW flux is interpolated for all daylight hours using models of the albedo variation with solar zenith angle (Suttles et al. 1988). Monthly mean albedos are calculated by summing the modeled SW flux values and dividing that sum by the sum of solar incident flux from the same hours. Monthly mean SW flux is calculated by multiplying the monthly mean albedo by a more precise value of monthly mean solar incident flux that is produced by integrating the solar incident flux over all days of the month.

Finally, the TOA LW and SW fluxes are averaged on zonal and global scales using the appropriate area weighting functions for each latitude.

3.5. Technical Basis

The ultimate goal of radiation budget monitoring experiments such as ERBE (Barkstrom 1984; Barkstrom and Smith 1986) and CERES (Wielicki and Barkstrom 1991) is to accurately determine the components of the Earth's radiation budget on regional, zonal, and global spatial scales at various temporal resolutions. Regional and global analyses of the large sets of highly accurate satellite measurements of incoming and outgoing energy in the Earth's climate system can be achieved only by adequately sampling the radiation fields and properly averaging the data in space and time. The CERES Data Management System will produce a data product which is processed in a manner consistent with ERBE to provide a stable, long-term data set for monitoring and analyzing Earth's climate variations. The averaging processes which are used in the CERES ERBE-like processing are described below.

ERBE is the most accurate experiment to date for measuring the Earth's radiation budget (Barkstrom et al. 1990), the diurnal variability of radiation (Harrison et al. 1988; Hartmann et al. 1991; Cheruy et al. 1991), cloud-radiative forcing (Ramanathan et al. 1989a; Ramanathan et al. 1989b; Harrison et al. 1990b), and volcanic climate radiative forcing (Minnis et al. 1993). For a discussion of the ERBE errors, see Harrison et al. (1990b) and Barkstrom et al. (1990). The largest sources of uncertainty in the pre-ERBE radiation budget missions arose from errors due to calibration and stability, sampling, and data analysis methods. The ERBE instruments reflect an improved understanding of instrument operation and incorporate reliable calibration sources for better measurement accuracy.

ERBE used multiple satellites to account for widespread semiregular diurnal variations in cloudiness that can cause substantial errors in regional radiation budgets derived with single Sun-synchronous satellite measurements (Harrison et al. 1983). The multisatellite ERBE measurements, combined with models to estimate fluxes at unsampled hours, produced the best estimates to date of the diurnal variability of TOA radiation (Harrison et al. 1988; Harrison et al. 1990a; Hartmann et al. 1991).

CERES instruments will also be flown on multiple satellites to provide the diurnal sampling necessary to obtain accurate monthly flux averages using the ERBE-like interpolation techniques. The temporal coverage of the three CERES satellites (TRMM, EOS-AM, and EOS-PM) for 1 month of observations is shown in figure 3-1. The TRMM spacecraft is in a 35°-inclined, precessing orbit which covers all local times at the equator in slightly over 26 days. The EOS satellites are in Sun-synchronous orbits, sampling at the same local times each day. From figure 3-1, it is evident that a single satellite cannot provide sufficient temporal sampling to accurately estimate SW and LW fluxes at all local hours.

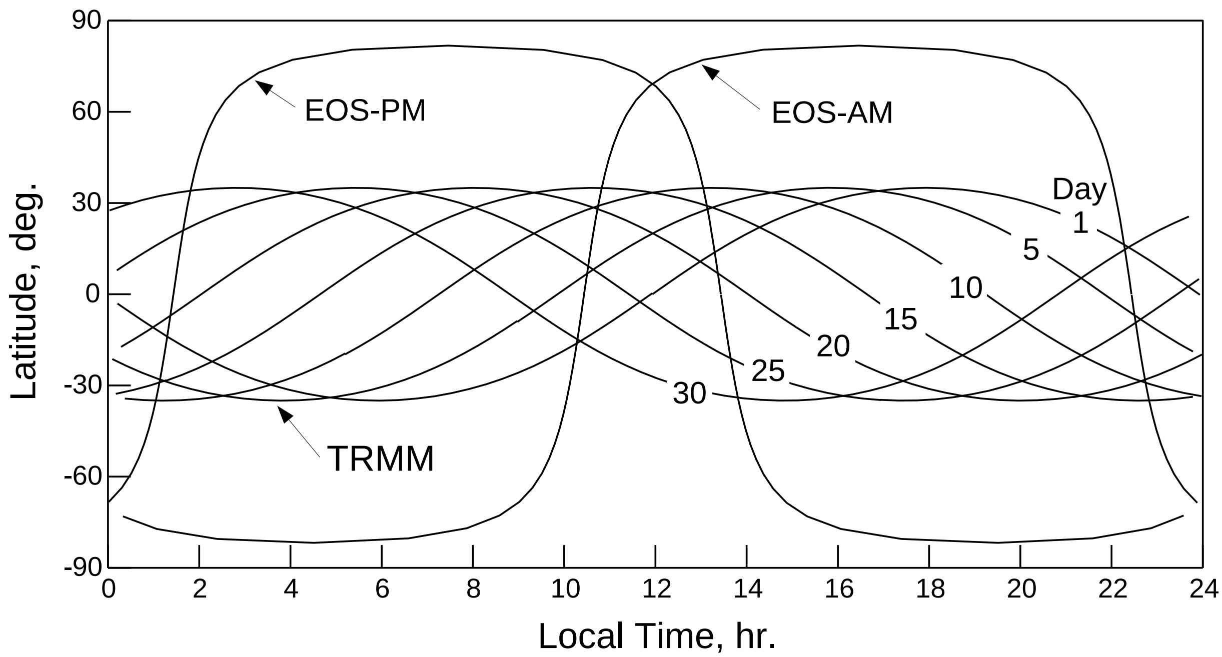


Figure 3-1. Temporal coverage of CERES satellites.

For ERBE, a comprehensive set of LW and SW angular dependence models was developed (Suttles et al. 1988 and 1989) and used to convert radiances to fluxes. A method for separating and identifying clear-sky and cloud-contaminated measurements (Wielicki and Green 1989) was constructed to improve radiance interpretation for selecting the correct angular models and to better understand the effects of clouds. Geostationary satellite data were used to develop a more accurate technique for averaging the data over the diurnal cycle (Brooks and Minnis 1984).

All of these improvements in the instruments, satellite sampling, and the data processing system allowed ERBE to meet many of the goals of the scientific community. CERES will make further improvements in ERB measurements, particularly in determining more accurate and com-prehensive cloud information. However, in the interest of compiling a long-term, consistent data set for climate studies, an ERBE-like data product will be produced.

3.5.1. Temporal Interpolation and Spatial Averaging

The first step in the averaging process is to sort the data in space and time. CERES data enter this subsystem as a chronologically-ordered stream of flux measurements. Spatially, these data are averaged and processed on an ERBE $2.5° \times 2.5°$ grid. Each region (grid box) is processed independently from all others. Within each region, a month of CERES measurements is sorted and averaged into local time intervals of one hour (referred to as hour boxes). There is a maximum of 744 hour boxes in a month (24 hours/day $\times$ 31 days).

The averaging of the LW flux is straightforward. All observations from a region that were measured within an hour box are linearly combined. Since albedo is a function of solar zenith angle, each SW measurement is first corrected to the central time, latitude, and longitude of the regional hour box into which it is collected. The temporal correction is performed using 12 ADM's. As shown in figure 3-2, there are separate ADM's for the five ERBE clear-sky geographical scene types (ocean, land, snow,

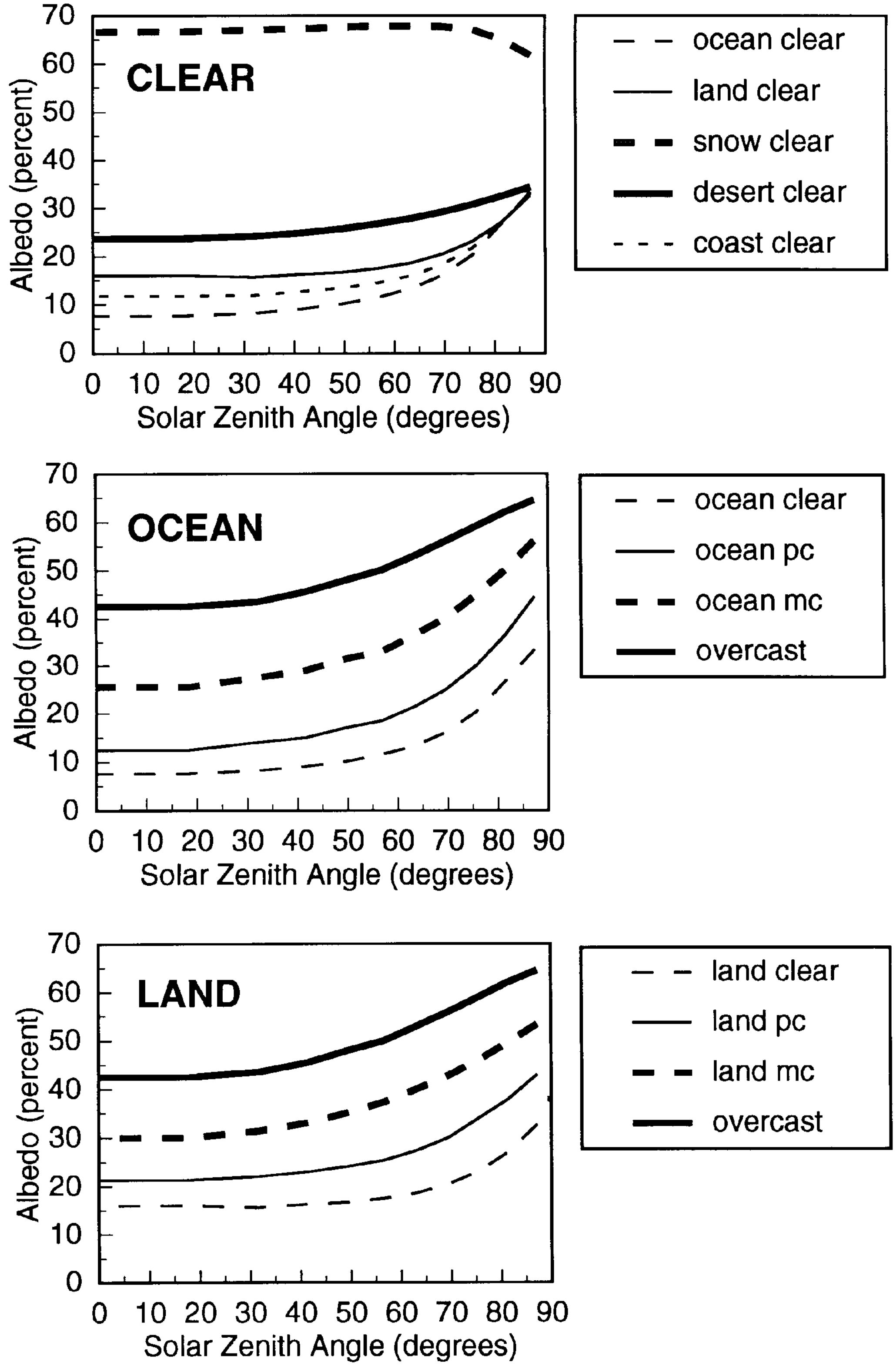


Figure 3-2. ERBE angular distribution models (ADM's).

desert, and coast). Over land and ocean surfaces, there are models for partly cloudy and mostly cloudy ERBE scene classifications. Finally, a single model is used for overcast conditions over all surfaces. The ADM's for partly and mostly cloudy coastal scenes are not shown. Within each hour box, a separate mean albedo is calculated for each cloud class, and a histogram of cloud class is also retained. The geographic scene type for each region is constant for a month.

3.5.2. Total-Sky TOA LW Flux

The ERBE TSA algorithm was designed to provide daily model fits to the TOA LW flux data as well as monthly averages of these data. To accomplish this goal, an estimate of LW flux is made for every hour box. This interpolation is performed in one of two ways, depending on the geographic scene type of the region.

Over ocean regions, there is little diurnal variability in LW flux due to solar insulation. The greatest variations in LW flux over the oceans occur due to changes in the amount and types of clouds. Therefore, no attempt is made to develop complex models for estimating the LW flux between the times of observations. Rather, it is assumed that changes in LW flux are due to changes in cloud conditions, and that this change is linear. Therefore, simple linear interpolation is used to provide a value of LW flux for each hour box not observed by CERES. At the beginning of the month, all hours preceding the first observation are filled with the value from the first observed time. The same procedure is applied at the end of the month using the last observed LW flux. This technique is also used for regions designated as either snow-covered or coastal.

Over land and desert regions, the effects of solar heating are much more pronounced than over ocean regions. During relatively cloud-free periods, there is generally a sinusoidal variation in LW flux over the daylight hours. In order to account for this variation, these regions are treated in a different manner from oceans in the TSA algorithm. For any day when an observation was made during daylight hours and during the preceding and following nights, the LW flux for the remaining hours of the day is modeled by fitting a half-sine curve to the observations. The modeling is performed by linear interpolation on days lacking the required observations or having any daylight observations of LW flux that are less than the nighttime values, or when the resultant half-sine curve has a negative amplitude.

The results of this type of interpolation are demonstrated in figure 3-3 that shows a time series of ERBE scanner data from April 1985 over a 2.5° region in eastern New Mexico. In this figure, observations are represented by circles, and the interpolated values are displayed as the solid line. The early part of the month was relatively clear, and half-sine fits were performed on days 1, 2, 4, 6, 7, and 8. However, on days 10, 11, and 12, no half-sine fit was used since low values of LW were observed in the late afternoon, which indicates that clouds must have been developing. In such cases, the half-sine fit is not realistic, and linear interpolation is used.

Once all hour boxes for the month have been filled with a value of LW flux, it is a simple matter to calculate daily, monthly-hourly, and monthly means. Two slightly different techniques are used to compute monthly means. In the first method (monthly-daily), a daily mean is computed by averaging the 24-hour box values for each day. The monthly mean TOA LW flux, $\bar{F}_{LW}$, is then computed by averaging all of the daily means:

$$\bar{F}_{LW} = \sum_{d=1}^{D} \frac{\sum_{h=1}^{24} F_{LW}(d,h)/24}{D} \tag{3.1}$$

where $F_{LW}(d, h)$ is the TOA LW flux for day d and local hour h, and D is the total number of days in the month. In the second method (monthly-hourly), hour box values for all days in which an observation

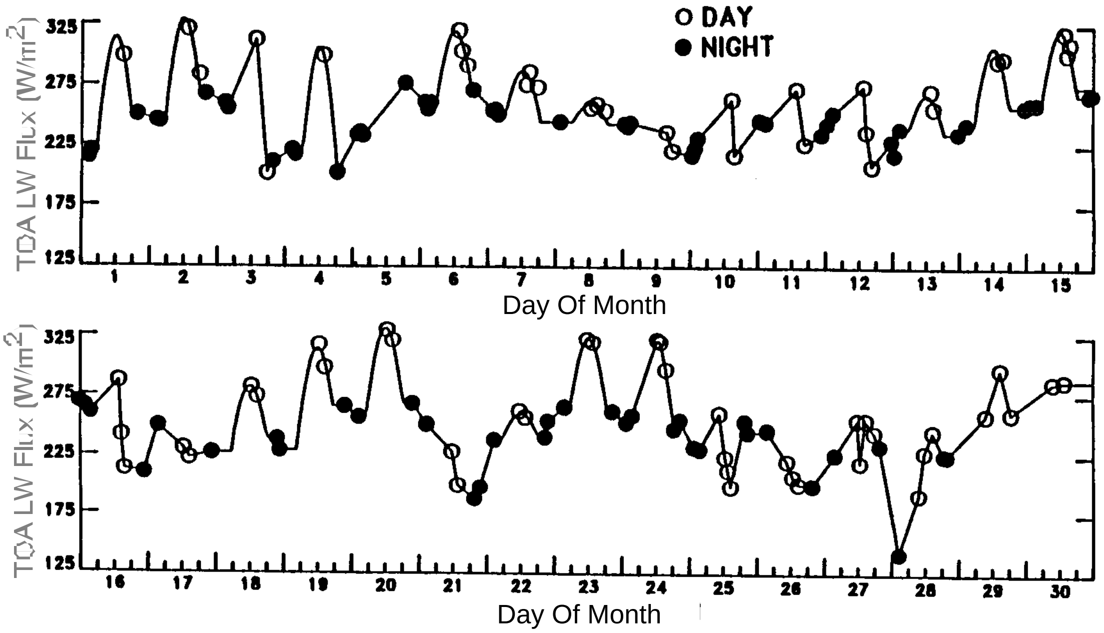


Figure 3-3. Time series of ERBS and NOAA-9 ERBE scanner TOA LW flux data and diurnal models for a 2.5° region in eastern New Mexico in April 1985.

was made are averaged at each local hour. The resulting 24 monthly-hourly means are then averaged to produce a monthly mean:

$$\bar{F}_{LW} = \sum_{h=1}^{24} \frac{\sum_{d=1}^{D_{LW}} F_{LW}(d,h)/D_{LW}}{24} \tag{3.2}$$

where D_{LW} is the total number of days in the month with at least one LW measurement. The two estimates of monthly mean LW flux will be equal unless there were days during the month when no observations were made.

3.5.3. Clear-Sky TOA LW Flux

The above algorithm works very well for total-sky LW flux for regions that are well-sampled in local time. However, problems may arise when applying this technique to clear-sky LW flux data. The ERBE cloud classification procedure is quite restrictive in terms of classifying an observation as clear (Wielicki and Green 1989). Also, there are many regions over the globe where cloudy conditions prevail throughout the month. Consequently, a region may have a very limited number of clear-sky observations during the month. In addition, satellite sampling patterns often result in a local-time bias in the occurrence of clear-sky measurements. An example of this is shown in figure 3-4 for the same 2.5° ERBE region over New Mexico discussed in the above section. For this case, with the exception of the two measurements from days 4 and 5, all of the limited number of clear-sky observations occurred during daylight hours. The lack of nighttime data means that the requirements for performing the diurnal half-sine fits are never met. The linear interpolation between the times of observation results in a monthly average that is unrealistically high because only daytime values are available. This problem is particularly serious over land and desert regions where large diurnal variations in LW flux are expected during clear-sky conditions. Since clear ocean areas generally have a much smaller LW flux diurnal

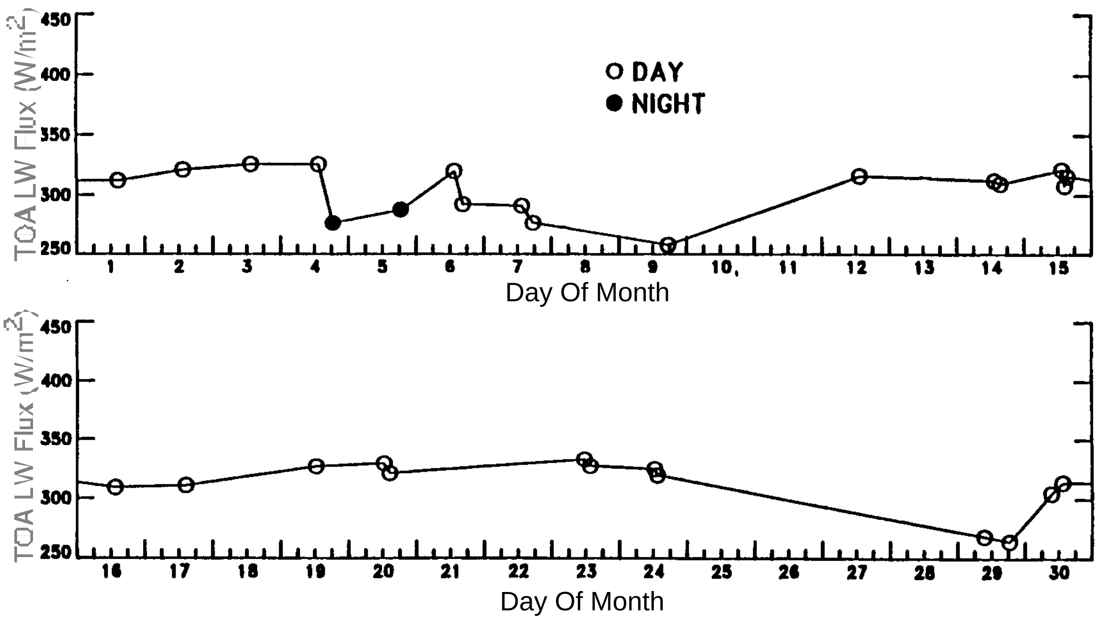


Figure 3-4. Time series of ERBS and NOAA-9 ERBE scanner clear-sky TOA LW flux data and diurnal models for a 2.5° region in eastern New Mexico in April 1985.

change, the day-night sampling bias does not severely affect the ocean monthly means. Therefore, in ocean regions, the clear-sky LW flux is averaged in a manner identical to the total-sky data.

Because of these problems associated with obtaining accurate averages of clear-sky LW flux over land and deserts, an improved TSA algorithm has been developed that involves calculating a single diurnal fit to the monthly ensemble of all clear-sky LW flux data. In the clear-sky case, it is reasonable to process all of the measurements together because the scene is essentially unchanged throughout the month and, consequently, the variance of measurements at the same local hour is expected to be small. Some exceptions occur due to scene variability of the measurement footprints within the region, changing atmospheric conditions such as water vapor content, wind, and surface temperature during the month, cloud contamination of presumably clear-sky scenes, and possible errors due to measurements taken at high viewing zenith angles. The underlying assumption is that this variability is small relative to the overall diurnal variation and can be effectively averaged out for a region having several clear-sky observations over the course of a month.

The clear-sky LW flux averaging technique is demonstrated in figure 3-5. The data shown in figure 3-4 have been sorted and averaged for the entire month in terms of local hour. The daytime points (open symbols) are then modeled using a least-squares half-sine fit weighted by the number of measurements at each local hour during the month. The nighttime data (filled symbols) are simply averaged and the constant value is used for all nighttime hours. The monthly mean is then calculated by averaging the fit over 24 hours if the fit meets five basic criteria:

(a) There must be at least one daylight measurement located more than one hour from the terminator

(b) There must be at least one nighttime measurement

(c) The least squares half-sine fit to the daylight data produces a positive amplitude

(d) The peak value of the fit must not exceed 400 $W\text{-}m^{-2}$

(e) The length of day 15 of the month must be greater than 2 hours

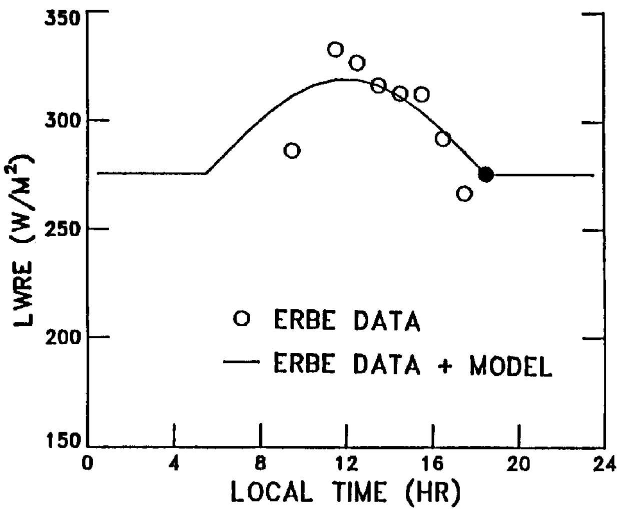


Figure 3-5. ERBE time averaged monthly-hourly clear-sky TOA LW flux results for the region shown in figure 3-4.

If these criteria are not met, no monthly mean TOA LW clear-sky flux is calculated for the region. Since the modeling process is performed on data accumulated throughout the month, daily means are not calculated for land and desert regions.

This technique produces realistic values of monthly mean clear-sky LW flux, even in regions with sparse data sampling. However, in many regions no estimate can be made due to the total lack of nighttime, clear-sky data due to persistent overcast conditions or the overly restrictive ERBE clear classification scheme. To compensate for missing nighttime data, the clear-sky averaging algorithm attempts to correct for the misclassification of nighttime clear pixels as partly cloudy. For each nighttime hour box over land regions, a new clear-sky amount is estimated by assuming that 10% of the pixels classified as partly cloudy are actually clear. If the new clear-sky amount exceeds 5% and is greater than the original clear-sky percentage, then the clear-sky longwave flux is recalculated using the mean and standard deviation of the total longwave flux.

3.5.4. Total-Sky and Clear-Sky TOA SW Flux

The procedure for producing diurnal, monthly-hourly, and monthly means of SW flux is quite different from that for LW flux. Since TOA SW flux is obviously only pertinent to daylight hours, the difficulty of interpolating across day-night boundaries that causes problems in modeling sparsely sampled LW data is not encountered. Furthermore, as shown in figure 3-2, there exist well-developed models of the variation of albedo with solar zenith angle for various clear and cloudy backgrounds (Suttles et al. 1988). These angular distribution models (ADM’s) are used to interpolate observations to other times of the day. In addition, the clear-sky SW flux (or albedo) can be modeled in the same manner as the total-sky since the lack of nighttime clear data is not a factor.

As explained in the section on spatial averaging, for each hour box with an observation, a separate albedo is calculated for each of the four ERBE cloud classifications: clear, partly cloudy, mostly cloudy, and overcast. In addition, a frequency histogram of the relative quantity of each type is stored. Because the diurnal variability of SW radiation is pronounced even within a single hour, measured values are first adjusted to the nearest local solar half hour. For a given surface type and cloud cover category (i.e., scene type for selecting an ADM), the normalized ADM function, $\delta_i(\mu_o)$, at time t is defined as the ratio of the albedo at time t and the albedo at overhead sun:

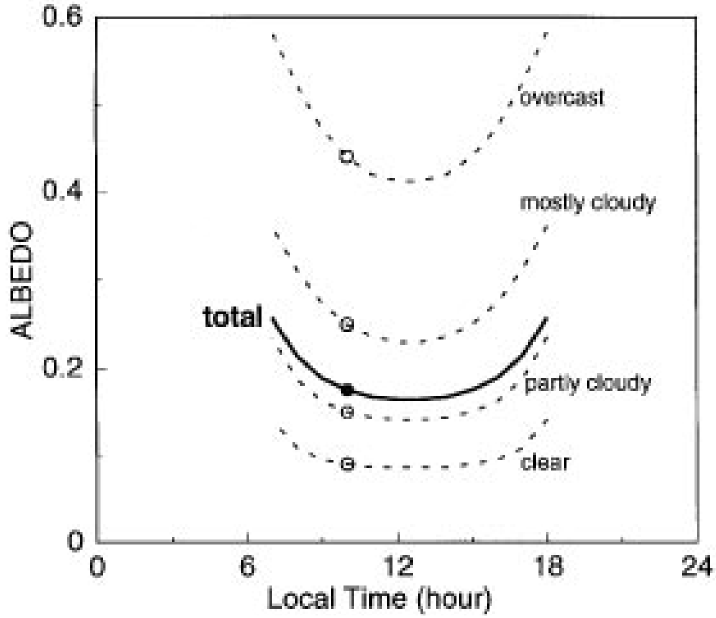


Figure 3-6. An example of time interpolation of albedo for days with only 1 hour of observation.

$$\delta_i(\mu_o(t)) = \frac{\alpha_{\mathrm{mod}_i}(\mu_o(t))}{\alpha_{\mathrm{mod}_i}(\mu_o = 1)} \tag{3.3}$$

where μ_o is the cosine of the solar zenith angle and α_{mod_i} is the ADM albedo for scene type i (from fig. 3-2). The albedo at any time t' (e.g., at the local solar half hour) can be expressed as the product of the observed albedo and the ratio of the normalized ADM functions from t' and the time of observation, t_{obs}:

$$\alpha_i(t') = \alpha_i(\mu_o(t_{obs}))\frac{\delta_i(\mu_o(t'))}{\delta_i(\mu_o(t_{obs}))} \tag{3.4}$$

For days with only one SW flux measurement, each of the four cloud type albedos from the hour of observation is modeled to all daylight hours using equation (3.4) and the appropriate ADM’s. This modeling is illustrated in figure 3-6. The albedos for the four cloud types are then recombined by weighting each cloud type albedo with the appropriate areal coverage fraction to obtain the mean albedo at each hour for the entire region (solid line in fig. 3-6). This process assumes that the relative abundance of the cloud classifications remains constant throughout the day.

For days with more than one measurement, this technique is modified as illustrated in figure 3-7. This figure presents albedos for all hours for each of the two measurements individually, and then shows how the two are combined to determine the best estimates of albedo. All daylight hours preceding the first measurement of the day and following the last measurement assume constant cloud class from the nearest measurement. These hours are modeled using equation (3.4) in the single measurement case. For hours between two measurements, it is assumed that the cloud histograms are varying linearly over that span. The four cloud type albedos are modeled from each surrounding measurement using equation (3.4) and the appropriate ADM's. Total albedo for each hour between the two measurements is then produced by inversely weighting the two estimates by the time from the hour of interest.

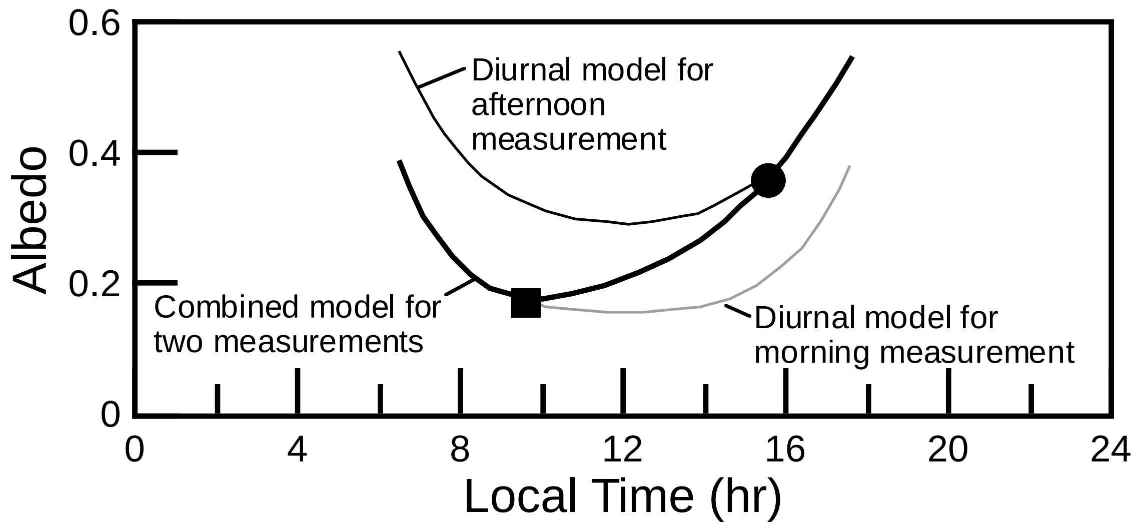


Figure 3-7. An example of time interpolation of albedo with 2 hours of observation during a day.

Monthly means are calculated once all hours are filled with albedo values for days with at least one measurement. The SW flux at each hour *h* of a given day *d* is:

$$F_{SW}(d, h) = E_o(d)\mu_o(d, h)\alpha(d, h) \tag{3.5}$$

where E_o is the mean daily distance-corrected solar constant. The SW flux is summed over all hours for days with measurements and divided by a summation of solar incident flux over the same hours to produce a monthly mean albedo:

$$\bar{\alpha} = \sum_{d=1}^{D_{SW}} \left(\sum_{h=1}^{24} F_{SW}(d, h)/24 \right) / D_{SW} / S_o \tag{3.6}$$

where $F_{SW}(d,h)$ is the TOA SW flux for day *d* and local hour *h*, D_{SW} is the total number of days in the month with at least one SW measurement, and S_o is the summed solar incident SW flux. Monthly mean SW flux, $\bar{F}_{SW}$ is then calculated by multiplying monthly mean albedo by the incident solar flux integrated and averaged over all hours of the month:

$$\bar{F}_{SW} = \alpha S'_o \tag{3.7}$$

where S'_o is the integrated solar incident SW flux.

Mean clear-sky SW flux is produced in a similar manner. In fact, the process is simpler because only the clear albedo from each hour box needs to be interpolated to non-measured hours. Again, only days with at least one measurement are filled using the clear-sky ADM's, and values from these days are combined to produce daily, monthly-hourly, and monthly means.

3.5.5. Zonal and Global Means

Zonal and global means of TOA LW and SW flux are calculated in the same manner as used with ERBE data. Since this product is produced on the ERBE 2.5° equal-angle grid, the regional means must be weighted by area when computing global means. The 2.5° regional data will also be nested into 5° and 10° grids as was done with ERBE.

3.6. Uncertainty Estimates

Although a complete, rigorous error analysis for all of the ERBE products is not yet available, several studies of the ERBE error sources have resulted in reliable estimates of the uncertainties in monthly mean TOA LW and SW radiation. Bias errors for monthly mean regional total-sky fluxes are less than 1 W-m^{-2}. The rms uncertainties in total-sky LW and SW fluxes are estimated to be 3 W-m^{-2} and 5 W-m^{-2}, respectively. In terms of SW albedo, the error is approximately ±0.014. The rms errors in clear-sky LW and SW fluxes are estimated to be 2 W-m^{-2}. The clear-sky LW fluxes, however, may be overestimated by about 4 W-m^{-2}. The clear-sky reflected flux is overestimated by approximately 1 W-m^{-2}. For an overview of the uncertainties in the ERBE monthly mean flux values, see Harrison et al. (1990b).

3.7. Strategic Concerns

Estimates of surface fluxes can be produced using TOA-to-surface parameterization schemes and included as part of the archived output from the ERBE-like processing of subsystem 3. These surface fluxes were originally planned for inclusion with the ERBE-like products. However, it has been decided that they will not be included in subsystem 3 for Release 2.1, in order for this subsystem to produce only truly ERBE-like results and also to eliminate the need for the ancillary meteorological data necessary for the parameterizations. Surface fluxes will be produced in subsystem 10.

The ERBE TSA currently extrapolates total-sky LW as a constant from the first observation back to the beginning of the month and from the last observation forward to the end of the month. The simple solution to the problems caused by this is to always average using only those days that contain at least one measurement.

The 2.5° regional data may not be nested into 5° and 10° grids as was done with ERBE. These two additional product spatial resolutions were provided by ERBE as a convenience to the user for comparisons with the ERBE non-scanner data. Eliminating these products would reduce the data volume, and the nesting can easily be performed by research analysts using the basic 2.5° data.

A primary goal of the ERBE-like product is to provide radiation budget data that are directly comparable with the ERBE data set. The possibility of a reprocessing of the ERBE data set is currently under consideration. The main changes planned include a new set of bidirectional models, new directional models, revised a priori LW clear-sky thresholds, and the elimination of monthly mean estimates for regions with insufficient sampling. Any changes to the ERBE processing that are included in the reprocessing will also be incorporated into the CERES ERBE-like product.

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Appendix A

Input Data Products

ERBE-like Averaging to Monthly TOA Fluxes (Subsystem 3.0)

This appendix describes the data products which are used by the algorithms in this subsystem. Table A-1 below summarizes these products, listing the CERES and EOSDIS product codes or abbreviations, a short product name, the product type, the production frequency, and volume estimates for each individual product as well as a complete data month of production. The product types are defined as follows:

Archival products: Assumed to be permanently stored by EOSDIS
Internal products: Temporary storage by EOSDIS (days to years)
Ancillary products: Non-CERES data needed to interpret measurements

The following pages describe each product. An introductory page provides an overall description of the product and specifies the temporal and spatial coverage. The table which follows the introductory page briefly describes every parameter which is contained in the product. Each product may be thought of as metadata followed by data records. The metadata (or header data) is not well-defined yet and is included mainly as a placeholder. The description of parameters which are present in each data record includes parameter number (a unique number for each distinct parameter), units, dynamic range, the number of elements per record, an estimate of the number of bits required to represent each parameter, and an element number (a unique number for each instance of every parameter). A summary at the bottom of each table shows the current estimated sizes of metadata, each data record, and the total data product. A more detailed description of each data product will be contained in a user's guide to be published before the first CERES launch.

Table A-1. Input Products Summary

Product code		Name	Type	Frequency	Size, MB	Monthly size, MB
CERES	EOSDIS					
EDDB/EID-6	None	ERBE-like daily database	Internal	1/day	6.5	202

ERBE-like Daily Data Base (EDDB/EID-6)

The EID-6 product is generated daily by the ERBE-like Inversion Subsystem (2.0). It contains regional averages at several parameters on the ERBE 2.5-degree equal-angle grid. The following table shows each parameter passed from the ERBE-like Inversion Subsystem (2.0) on the EID-6 to the ERBE-like Monthly Time and Space Averaging Subsystem (3.0).

Level: 2
Type: Internal
Frequency: 1/Day

Portion of Globe Covered
File: Regional
Record: Individual Region

Time Interval Covered
File: Day
Record: N/A

Portion of Atmosphere Covered
File: TOA

Table A-2. ERBE-like Daily Regional Averages (EDDB/EID-6)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
EDDB						
EDDB_File_Header						
EDDB File Header		N/A		TBD	TBD	
EDDB_Regional_Data_Records						
Region number	1	N/A	1..10368	1	64	1
Julian day	2	day	2449353..2458500	1	64	2
Julian time	3	day	0..1	1	64	3
Regional_Average_Estimates						
SW flux average value	4	Wm^{-2}	0..1400	1	64	4
LW flux average value	5	Wm^{-2}	0..400	1	64	5
Retional_SW_Statistics						
SW flux number of values	6	N/A	0..500	1	64	6
SW flux standard deviation	7	Wm^{-2}	0..1400	1	64	7
SW flux minimum value	8	Wm^{-2}	0..1400	1	64	8
SW flux maximum value	9	Wm^{-2}	0..1400	1	64	9
Regional_LW_Statistics						
LW flux number of values	10	N/A	0..500	1	64	10
LW flux standard deviation	11	Wm^{-2}	0..400	1	64	11
LW flux minumum value	12	Wm^{-2}	0..400	1	64	12
LW flux maximum value	13	Wm^{-2}	0..400	1	64	13
Geo_Scene						
Geographic Scene Type	14	N/A	1..5	1	64	14
Clear-sky fraction	15	N/A	0..1	1	64	15
Partly-cloudy fraction	16	N/A	0..1	1	64	16
Mostly-cloudy Fraction	17	N/A	0..1	1	64	17
Overcast Fraction	18	N/A	0..1	1	64	18
Albedos						
Albedo for clear-sky	19	N/A	0..1	1	64	19
Albedo for partly-cloudy	20	N/A	0..1	1	64	20
Albedo for mostly-cloudy	21	N/A	0..1	1	64	21
Albedo for overcast	22	N/A	0..1	1	64	22
Angular_Averages						
Average of cosines of solar zenith angles	23	N/A	0..1	1	64	23
Average of spacecraft zenith angles	24	deg	0..90	1	64	24
Average of relative azimuth angles	25	deg	0..180	1	64	25
Clear-Sky_Statistics						
Clear-sky albedo standard deviation	26	N/A	0..1	1	64	26
Clear-sky LW flux average value	27	$W\text{-}m^{-2}$	0..400	1	64	27
Clear-sky LW flux stancard deviation	28	$W\text{-}m^{-2}$	0..400	1	64	28
Clear-sky LW flux number of values	29	N/A	0..500	1	64	29
Spares						
Spare	30	N/A	N/A	1	64	30
Spare	31	N/A	N/A	1	64	31

Total Meta Bits/File:	**TBD**
Total Data Bits/Record	**1984**
Total Records/File (TRMM)	**27597**
Total Data Bits/File	**54752448**
Total Bits/File	**54752448**

Appendix B

Output Data Products

ERBE-like Averaging to Monthly TOA Fluxes (Subsystem 3.0)

This appendix describes the data products which are produced by the algorithms in this subsystem. Table B-1 below summarizes these products, listing the CERES and EOSDIS product codes or abbreviations, a short product name, the product type, the production frequency, and volume estimates for each individual product as well as a complete data month of production. The product types are defined as follows:

Archival products: Assumed to be permanently stored by EOSDIS
Internal products: Temporary storage by EOSDIS (days to years)

The following pages describe each product. An introductory page provides an overall description of the product and specifies the temporal and spatial coverage. The table which follows the introductory page briefly describes every parameter which is contained in the product. Each product may be thought of as metadata followed by data records. The metadata (or header data) is not well-defined yet and is included mainly as a placeholder. The description of parameters which are present in each data record includes parameter number (a unique number for each distinct parameter), units, dynamic range, the number of elements per record, an estimate of the number of bits required to represent each parameter, and an element number (a unique number for each instance of every parameter). A summary at the bottom of each table shows the current estimated sizes for metadata, each data record, and the total data product. A more detailed description of each data product will be contained in a user’s guide to be published before the first CERES launch.

Table B-1. Output Products Summary

Product code						Monthly
CERES	EOSDIS	Name	Type	Frequency	Size, MB	size, MB
ES-9	CER03	Regional averages	archival	1/month	66.0	66
ES-4	CER13	Geographical averages	archival	1/month	11.3	11
ES-4G	CER14	Gridded averages	archival	1/month	18.2	18

ERBE-like Monthly Regional Averages (ES-9)

EOSDIS Product Code: CER03

The ES-9 stores data for each 2.5-deg region observed during a month. There are 10368 possible regions, and a given region is viewed by the scanner several times as the spacecraft passes overhead. For each region, data are stored by the hour for each hour of each day in the month. Stored data includes the mean estimates of shortwave and longwave radiant flux at the TOA, the standard deviations of these estimates, the maximum and minimum estimate, and scene information or cloud condition. Similar parameters are determined for those scanner measurements that were identified as viewing clear-sky areas. Daily, monthly hourly, and monthly averages are also stored. A complete listing of parameters for this data product can be found in Table B-2.

Level: 3
Type: Archival
Frequency: 1/Month

Portion of Globe Covered
File: Global
Record: Regional

Time Interval Covered
File: 1 Month
Record: Hour Box Data

Portion of Atmosphere Covered
File: TOA

Table B-2. ERBE-like Monthly Regional Averages (ES-9) (1 of 3)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
ES-9						
ES-9_File_Header						
File header		N/A		TBD	TBD	
ES-9_Record_Level_Data_Scale_Factors						
Scale factors		N/A		93	16	
ES-9_Data_Records						
Region number	1	N/A	1..10368	1	16	1
Geographic scene type	2	N/A	1 .. 5	1	16	2
Sene fraction histogram	3	N/A	N/A	4	16	3
Monthly_Averages_Day						
SW flux	4	W m^{-2}	0 .. 1400	1	16	7
SW flux minimum value	5	W m^{-2}	0 .. 1400	1	16	8
SW flux maximum value	6	W m^{-2}	0 .. 1400	1	16	9
SW flux standard deviation	7	W m^{-2}	0 .. 1400	1	16	10
SW flux number of days with at least one sample	8	day	0 .. 31	1	16	11
LW flux	9	W m^{-2}	50 .. 400	1	16	12
LW flux minimum value	10	W m^{-2}	50 .. 400	1	16	13
LW flux maximum value	11	W m^{-2}	50 .. 400	1	16	14
LW flux standard deviation	12	W m^{-2}	0 .. 350	1	16	15
LW flux number of days with at least 1 sample	13	day	0 .. 31	1	16	16
Albedo	14	N/A	0 .. 1	1	16	17
Net flux	15	W m^{-2}	-200 .. 200	1	16	18
Monthly total integrated solar incidence	16	N/A	0 .. 500000	2	16	19
Clear sky SW flux	17	W m^{-2}	0 .. 1400	1	16	21
Clear sky SW flux minimum value	18	W m^{-2}	0 .. 1400	1	16	22
Clear sky SW flux maximum value	19	W m^{-2}	0 .. 1400	1	16	23
Clear sky SW flux standard deviation	20	W m^{-2}	0 .. 1400	1	16	24
Clear sky SW flux number of days with at least 1 sample	21	day	0 .. 31	1	16	25
Clear sky LW flux average flux	22	W m^{-2}	50 .. 400	1	16	26
Clear sky LW flux minimum value	23	W m^{-2}	50 .. 400	1	16	27
Clear sky LW flux maximum value	24	W m^{-2}	50 .. 400	1	16	28
Clear sky LW flux standard deviation	25	W m^{-2}	0 .. 350	1	16	29
Clear sky LW flux number of days with at least 1 sample	26	day	0 .. 31	1	16	30
Clear sky albedo	27	N/A	0 .. 1	1	16	31
Clear sky net radiant flux	28	W m^{-2}	-200 .. 200	1	16	32
Clear sky solar incidence	29	N/A	0 .. 500000	2	16	33
Monthly_Averages_Hour						
SW flux	30	W m^{-2}	0 .. 1400	1	16	35
SW flux minimum value	31	W m^{-2}	0 .. 1400	1	16	36
SW flux maximum value	32	W m^{-2}	0 .. 1400	1	16	37
SW flux standard deviation	33	W m^{-2}	0 .. 1400	1	16	38
SW flux number of hours with at least 1 sample	34	hour	0 .. 24	1	16	39
LW flux	35	W m^{-2}	50 .. 400	1	16	40
LW flux minimum value	36	W m^{-2}	50 .. 400	1	16	41
LW flux maximum value	37	W m^{-2}	50 .. 400	1	16	42
LW flux standard deviation	38	W m^{-2}	0 .. 350	1	16	43
LW flux number of hours with at least 1 sample	39	hour	0 .. 24	1	16	44
Albedo	40	N/A	0 .. 1	1	16	45
Net flux	41	W m^{-2}	-200 .. 200	1	16	46
Solar incidence	42	N/A	0 .. 500000	2	16	47
Clear sky SW flux	43	W m^{-2}	0 .. 1400	1	16	49
Clear sky SW flux minimum value	44	W m^{-2}	0 .. 1400	1	16	50
Clear sky SW flux maximum value	45	W m^{-2}	0 .. 1400	1	16	51
Clear sky SW flux standard deviation	46	W m^{-2}	0 .. 1400	1	16	52
Clear sky SW flux number of hours with at least 1 sample	47	hour	0 .. 24	1	16	53
Clear sky LW flux	48	W m^{-2}	50 .. 400	1	16	54

Table B-2. ERBE-like Monthly Regional Averages (ES-9) (2 of 3)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
Clear sky LW flux minimum value	49	W m^{-2}	50 .. 400	1	16	55
Clear sky LW flux maximum value	50	W m^{-2}	50 .. 400	1	16	56
Clear sky LW flux standard deviation	51	W m^{-2}	0 .. 350	1	16	57
Clear sky LW flux number of hours with at least 1 sample	52	hour	0 .. 24	1	16	58
Clear sky albedo	53	N/A	0 .. 1	1	16	59
Clear sky net flux	54	W m^{-2}	-200 .. 200	1	16	60
Clear sky solar incidence	55	W m^{-2}	0 .. 500000	2	16	61
Monthly_Averages_Daily						
Solar constant, distance corrected	56	W m^{-2}	1300 .. 1450	31	16	63
SW flux	57	W m^{-2}	0 .. 1400	31	16	94
SW flux minimum value	58	W m^{-2}	0 .. 1400	31	16	125
SW flux maximum value	59	W m^{-2}	0 .. 1400	31	16	156
SW flux standard deviation	60	W m^{-2}	0 .. 1400	31	16	187
SW flux number of hours with at least 1 sample	61	hour	0 .. 24	31	16	218
LW flux	62	W m^{-2}	50 .. 400	31	16	249
LW flux minimum value	63	W m^{-2}	50 .. 400	31	16	280
LW flux maximum value	64	W m^{-2}	50 .. 400	31	16	311
LW flux standard deviation	65	W m^{-2}	0 .. 350	31	16	342
LW flux number of hours with at least 1 sample	66	hour	0 .. 24	31	16	373
Albedo	67	N/A	0 .. 1	31	16	404
Solar incidence	68	W m^{-2}	0 .. 20000	62	16	435
Clear sky SW flux	69	W m^{-2}	0 .. 1400	31	16	497
Clear sky SW flux minimum value	70	W m^{-2}	0 .. 1400	31	16	528
Clear sky SW flux maximum value	71	W m^{-2}	0 .. 1400	31	16	559
Clear sky SW flux standard deviation	72	W m^{-2}	0 .. 1400	31	16	590
Clear sky SW flux number of hours with at least 1 sample	73	hour	0 .. 24	31	16	621
Clear sky LW flux	74	W m^{-2}	50 .. 400	31	16	652
Clear sky LW flux minimum value	75	W m^{-2}	50 .. 400	31	16	683
Clear sky LW flux maximum value	76	W m^{-2}	50 .. 400	31	16	714
Clear sky LW flux standard deviation	77	W m^{-2}	0 .. 350	31	16	745
Clear sky LW flux number of hours with at least 1 sample	78	hour	0 .. 24	31	16	776
Clear sky albedo	79	N/A	0 .. 1	31	16	807
Monthly_Averages_Hourly						
SW flux	80	W m^{-2}	0 .. 1400	24	16	838
SW flux minimum value	81	W m^{-2}	0 .. 1400	24	16	862
SW flux maximum value	82	W m^{-2}	0 .. 1400	24	16	886
SW flux standard deviation	83	W m^{-2}	0 .. 1400	24	16	910
SW flux number of days with at least 1 sample	84	day	0 .. 31	24	16	934
SW sum of estimates	85	W m^{-2}	0 .. 45000	48	16	958
SW sum of estimates squared	86	W m^{-4}	0 .. 50000000	48	16	1006
LW flux	87	W m^{-2}	50 .. 400	24	16	1054
LW flux minimum value	88	W m^{-2}	50 .. 400	24	16	1078
LW flux maximum value	89	W m^{-2}	50 .. 400	24	16	1102
LW flux standard deviation	90	W m^{-2}	0 .. 350	24	16	1126
LW flux number of days with at least 1 sample	91	day	0 .. 31	24	16	1150
LW flux sum of estimates	92	W m^{-2}	0 .. 15000	48	16	1174
LW sum of estimates squared	93	W m^{-4}	0 .. 5000000	48	16	1222
Albedo	94	N/A	0 .. 1	24	16	1270
Solar incidence	95	W m^{-2}	0 .. 1450	48	16	1294
Clear sky SW flux	96	W m^{-2}	0 .. 1400	24	16	1342
Clear sky SW flux minimum value	97	W m^{-2}	0 .. 1400	24	16	1366
Clear sky SW flux maximum value	98	W m^{-2}	0 .. 1400	24	16	1390
Clear sky SW flux standard deviation	99	W m^{-2}	0 .. 1400	24	16	1414
Clear sky SW flux number of days with at least 1 sample	100	day	0 .. 31	24	16	1438
Clear sky SW sum of estimates	101	W m^{-2}	0..45000	48	16	1462

Table B-2. ERBE-like Monthly Regional Averages (ES-9) (3 of 3)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
Clear sky SW sum of estimates squared	102	W m^{-4}	0 .. 50000000	48	16	1510
Clear sky LW flux	103	W m^{-2}	50 .. 400	24	16	1558
Clear sky LW flux minimum value	104	W m^{-2}	50 .. 400	24	16	1582
Clear sky LW flux maximum value	105	W m^{-2}	50 .. 400	24	16	1606
Clear sky LW flux standard deviation	106	W m^{-2}	0 .. 350	24	16	1630
Clear sky LW flux number of days with at least 1 sample	107	day	0 .. 31	24	16	1654
Clear sky LW sum of estimates	108	W m^{-2}	0 .. 15000	48	16	1678
Clear sky LW sum of estimates squared	109	W m^{-4}	0 .. 5000000	48	16	1726
Clear sky albedo	110	W m^{-2}	0 .. 1	24	16	1774
Clear sky solar incidence	111	W m^{-2}	0 .. 1450	48	16	1798
Number_of_Monthly_Hour_boxes						
Number of hour boxes	112	Hour boxes	1 .. 744	1	16	1846
Monthly_Hourly_Daily						
Hour box number	113	N/A	1 .. 744	744	16	1847
Whole part of Julian date	114	day	2449353..2458500	1488	16	2591
Fractional part of Julian day	115	day	0 .. 1	744	16	4079
Scene fraction	116	N/A	0 .. 1	2976	16	4823
Albedo vector	117	N/A	0 .. 1	2976	16	7799
Cosine of the solar zenith angle	118	N/A	0 .. 1	744	16	10775
Satellite zenith angle	119	deg	0 .. 90	744	16	11519
Azimuth angle	120	deg	0 .. 360	744	16	12263
Solar incidence	121	W m^{-2}	0 .. 1450	744	16	13007
SW flux	122	W m^{-2}	0 .. 1400	744	16	13751
SW flux minimum value	123	W m^{-2}	0 .. 1400	744	16	14495
SW flux maximum value	124	W m^{-2}	0 .. 1400	744	16	15239
SW flux standard deviation	125	W m^{-2}	0 .. 1400	744	16	15983
SW flux number	126	N/A	TBD	744	16	16727
LW flux	127	W m^{-2}	50 .. 400	744	16	17471
LW flux minimum value	128	W m^{-2}	50 .. 400	744	16	18215
LW flux maximum value	129	W m^{-2}	50 .. 400	744	16	18959
LW flux standard deviation	130	W m^{-2}	0 .. 350	744	16	19703
LW flux number	131	N/A	TBD	744	16	20447
SW flux maximum difference	132	W m^{-2}	TBD	744	16	21191
LW flux maximum difference	133	W m^{-2}	TBD	744	16	21935
Clear sky albedo	134	N/A	0 .. 1	744	16	22679
Clear sky LW flux	135	W m^{-2}	50 .. 400	744	16	23423
Clear sky LW flux standard deviation	136	W m^{-2}	0 .. 350	744	16	24167
Clear sky LW flux number	137	N/A	TBD	744	16	24911

Total Meta Bits/File:	TBD
Total Data Bits/Record:	410464
Total Records/File:	10368
Total Data Bits/File:	4255690752
Total Bits/File :	4255692240

(Note: Sizing estimates shown in this table assume that all 2.5-deg regions and all hour boxes contain data. The sizing estimate for the ES-9 in Table B-1 is for TRMM.)

ERBE-like Monthly Geographical Averages (ES-4)

EOSDIS Product Code: CER13

The ES-4 data is a regional, zonal, and global averages product. The instantaneous scanner estimates at the TOA are arranged temporally by hours, days, and the month. They are averaged spatially by regions, latitude zones, and the globe. The ES-4 product contains a header record, a record of file address map, a record of data scale factors, and seven sets of data records. Each data record set corresponds to a regional, nested regional, zonal, or global average. There are 10368 2.5-degree regions for the ERBE-like data. Therefore, there is a maximum of 10368 records in the 2.5-degree regional record set. The second set of records is the 2.5-degree nested to 5.0 degree regional data, which constitutes 2592 records. The third set of records is the 5.0 degree nested to 10.0 degree regional data, which constitutes 648 records. The fourth, fifth, and sixth sets of records are the 2.5 degree, 5.0 degree, and 10.0 degree zonally averaged data which constitute 72, 36, and 18 records, respectively. The last set is the global data, which constitutes 3 records. A complete listing of parameters for this data product can be found in Table B-3.

Level: 3
Type: Archival
Frequency: 1/Month

Time Interval Covered
File: Month
Record: Month

Portion of Globe Covered
File: Regional, zonal, global
Record: Regional, zonal, global

Portion of Atmosphere Covered
File: TOA

Table B-3. ERBE-like Monthly Geographical Averages (ES-4) (1 of 2)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
ES-4						
ES-4_Header:						
File header		N/A	N/A	TBD	TBD	
ES-4_Record_Mapping_Matrix (1 record)						
10 X 2 mapping matrix for spatial boundaries		N/A	N/A	20	32	
ES-4_Record_Data_Scaling (1 record)						
Scale factors for 32-bits Data		N/A	N/A	90	32	
Scale factors for 16-bits Data		N/A	N/A	345	16	
Scale factors for 8-bits Data		N/A	N/A	240	8	
ES-4_2.5-deg Regional Data Record (10368 records)						
32-bit_Data						
File ID	1	N/A	N/A	1	32	1
Solar Incidence for Monthly Averages by Day	2	W h m^{-2}	0 .. 500000	1	32	2
Monthly net radiant flux by day	3	W m^{-2}	-200 .. 200	1	32	3
Clear sky net radiant flux, monthly by day	4	W m^{-2}	-200 .. 200	1	32	4
Clear sky solar incidence, monthly by day	5	W m^{-2}	0 .. 500000	1	32	5
Monthly net radiant flux by hour	6	W m^{-2}	-200 .. 200	1	32	6
Solar incidence, monthly by hour	7	W h m^{-2}	0 .. 500000	1	32	7
Clear sky net radiant flux, monthly by hour	8	W m^{-2}	-200 .. 200	1	32	8
Clear sky solar incidence, monthly by hour	9	W h m^{-2}	0 .. 500000	1	32	9
Daily solar incidence	10	W h m^{-2}	0 .. 500000	31	32	10
Hourly solar incidence	11	W h m^{-2}	0 .. 500000	24	32	41
Clear sky solar incidence	12	W h m^{-2}	0 .. 500000	24	32	65
32-bit Spares	13	N/A	N/A	2	32	89
16-bit_Data						
Region number	14	N/A	1 .. 144	1	16	91
Year and month (YYMM) of data processed	15	N/A	N/A	1	16	92
Spacecraft code (TBD)	16	N/A	TBD	1	16	93
Longwave flux	17	W m^{-2}	50 .. 400	1	16	94
Shortwave flux	18	W m^{-2}	0 .. 1400	1	16	95
Monthly mean albedo	19	N/A	0 .. 1	1	16	96
Clear sky longwave flux	20	W m^{-2}	50 .. 400	1	16	97
Clear sky shortwave flux	21	W m^{-2}	0 .. 1400	1	16	98
Monthly mean clear sky albedo	22	N/A	0 .. 1	1	16	99
Longwave flux by the hour	23	W m^{-2}	50 .. 400	1	16	100
Shortwave flux by the hour	24	W m^{-2}	0 .. 1400	1	16	101
Monthly average albedo by the hour	25	N/A	0 .. 1	1	16	102
Clear sky longwave flux by the hour	26	W m^{-2}	50 .. 400	1	16	103
Clear sky shortwave flux by the hour	27	W m^{-2}	0 .. 1400	1	16	104
Clear sky Monthly averaged albedo by the hour	28	N/A	0 .. 1	1	16	105
Longwave flux, daily	29	W m^{-2}	50 .. 400	31	16	106
Short wave flux, daily	30	W m^{-2}	0 .. 1200	31	16	137
Monthly mean albedo, daily	31	N/A	0 .. 1	31	16	168
Clear sky longwave flux, daily	32	W m^{-2}	50 .. 400	31	16	199
Clear sky shortwave flux, daily	33	W m^{-2}	0 .. 1400	31	16	230
Monthly mean clear sky albedo, daily	34	N/A	0 .. 1	31	16	261
Longwave flux, hourly	35	W m^{-2}	50 .. 400	24	16	285
Shortwave flux, hourly	36	W m^{-2}	0 .. 1400	24	16	309
Monthly average albedo, hourly	37	N/A	0 .. 1	24	16	333
Clear sky longwave flux, hourly	38	W m^{-2}	50 .. 400	24	16	357
Clear sky shortwave flux, hourly	39	W m^{-2}	0 .. 1400	24	16	381
Clear sky Monthly averaged albedo, hourly	40	N/A	0 .. 1	24	16	405
8-bit_Data						
Number of observations for LW, daily	41	hour	0 .. 24	31	8	436
Number of observations SW, daily	42	hour	0 .. 24	31	8	467

Table B-3. ERBE-like Monthly Geographical Averages (ES-4) (2 of 2)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
Number of observations for clear sky LW, daily	43	hour	0 .. 24	31	8	498
Number of observations for clear sky SW, daily	44	hour	0 .. 24	31	8	529
Number of observations for LW, hourly	45	day	0 .. 31	24	8	560
Number of observations for SW, hourly	46	day	0 .. 31	24	8	584
Number of observations for clear sky LW, hourly	47	day	0 .. 31	24	8	608
Number of observations for clear sky SW, hourly	48	day	0 .. 31	24	8	632
Spares	49	N/A	N/A	20	8	656
ES-4_5.0-deg Nested Regional Data Record (2592 records)						
32-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	1	N/A	N/A	90	32	1
16-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	14	N/A	N/A	345	16	91
8-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	41	N/A	N/A	240	8	436
ES-4_10.0-deg Nested Regional Data Record (648 records)						
32-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	1	N/A	N/A	90	32	1
16-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	14	N/A	N/A	345	16	91
8-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	41	N/A	N/A	240	8	436
ES-4_2.5-deg Zonal Data Record (72 records)						
32-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	1	N/A	N/A	90	32	1
16-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	14	N/A	N/A	345	16	91
8-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	41	N/A	N/A	240	8	436
ES-4_5.0-deg Zonal Data Record (36 records)						
32-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	1	N/A	N/A	90	32	1
16-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	14	N/A	N/A	345	16	91
8-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	41	N/A	N/A	240	8	436
ES-4_10.0-deg Zonal Data Record (18 records)						
32-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	1	N/A	N/A	90	32	1
16-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	14	N/A	N/A	345	16	91
8-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	41	N/A	N/A	240	8	436
ES-4_Global Zonal Data Record (3 records)						
32-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	1	N/A	N/A	90	32	1
16-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	14	N/A	N/A	345	16	91
8-bit_Data						
Same parameters as in 2.5-deg Regional Data Record	41	N/A	N/A	240	8	436
Total Meta Bits/File:	TBD					
Total Data Bits/Record:	10320					
Total Records/File:	13739					
Total Data Bits/File:	141786480					
Total Bits/File :	141786480					

(Note: Sizing estimates shown in this table assume that all 2.5-deg regions and all hour boxes contain data. The sizing estimate for the ES-4 in Table B-1 is for TRMM.)

ERBE-like Monthly Gridded Averages (ES-4G)

EOSDIS Product Code: CER14

The ES-4G data product stores the same time and space averages as the ES-4 science data product, with the difference being the arrangement of the data. While the ES-4 is arranged by region, the ES-4G files present a gridded data product with all regions for a given data parameter grouped together. The regional presentation of the data is in the same order as that described for the ES-4 product. The 2.5 degree regional parameters are presented as 10368-element vectors, the 2.5 nested to 5.0 degree data is presented as 2592-element vectors, and the 5.0 nested to 10.0 degree data is presented as 648-element vectors. The 2.5, 5.0, and 10.0 degree zonal data is presented as 72, 36, and 18-element vectors respectively. The global data are presented as 3-element vectors.

The ES-4G data product is written on four output files. The first three files contains 2.5-deg regional data, 32-bit, 16-bit, and 8-bit data. The fourth file contains nested regional data, all zonal data, and global data. A complete listing of parameters for this data product can be found in Table B-4.

Level: 3
Type: Archival
Frequency: 1/Month

Time Interval Covered
File: Month
Record: Month

Portion of Globe Covered
File: Global, Zonal, Regional
Record: Global, Zonal, Regional

Portion of Atmosphere Covered
File: TOA

Table B-4. ERBE-like Monthly Gridded Averages (ES-4G) (1 of 8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
ES_4G_2.5-deg_Regional_32-bit_Data (File 1)						
Monthly_Averages_Day						
Solar Incidence						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W h m^{-2}	0 .. 500000	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Net Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W m^{-2}	-200 .. 200	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Clear Sky Net Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Average	3	W m^{-2}	-200 .. 200	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Clear Sky Solar Incidence						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W h m^{-2}	0 .. 500000	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Monthly_Averages_Hour						
Net Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W m^{-2}	-200 .. 200	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Solar Incidence						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W h m^{-2}	0 .. 500000	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Clear Sky Net Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W m^{-2}	-200 .. 200	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Clear Sky Solar Incidence						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W h m^{-2}	0 .. 500000	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Monthly_Averages_Daily						
Solar Incidence (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W h m^{-2}	0 .. 500000	10368	32	3
Spares	4	N/A	N/A	420	8	10371
Monthly_Averages_Hourly						
Solar Incidence (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W h m^{-2}	0 .. 500000	10368	32	3
Spares	4	N/A	N/A	420	8	10371

Table B-4. ERBE-like Monthly Gridded Averages (ES-4G) (2 of 8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
Clear Sky Solar Incidence (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	W h m^{-2}	0 .. 500000	10368	32	3
Spares	4	N/A	N/A	420	8	10371

Total Meta Bits/File:	TBD
Total Data Bits/Record:	335872
Total Records/File 1:	87
Total Data Bits/File 1:	29220864
Total Bits/File 1 :	29220864

Table B-4. ERBE-like Monthly Gridded Averages (ES-4G) (3 of 8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
ES_4G_2.5-deg_Regional_16-bit_Data (File 2)						
Monthly_Averages_Day						
LW Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	50 .. 400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
SW Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	0 .. 1400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Albedo						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	0 .. 1	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky LW Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	0 .. 1400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky SW Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	0 .. 400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky Albedo						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	0 .. 1	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Monthly_Averages_Hour						
LW Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	50 .. 400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
SW Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	0 .. 1400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Albedo						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	0 .. 1	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky LW Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	50 .. 400	10368	16	3
Spares	4	N/A	N/A	166	8	10371

Table B-4. ERBE-like Monthly Gridded Averages (ES-4G) (4 of 8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
Clear Sky SW Flux						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	0 .. 1400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky Albedo						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	0 .. 1	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Monthly_Averages_Daily						
LW Flux (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	50 .. 400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
SW Flux (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	50 .. 1400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Albedo (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	0 .. 1	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky LW Flux (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	50 .. 400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky SW Flux (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	0 .. 1400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky Albedo (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	0 .. 1	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Monthly_Averages_Hourly						
LW Flux (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	50 .. 400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
SW Flux (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	0 .. 1400	10368	16	3
Spares	4	N/A	N/A	166	8	10371

Table B-4. ERBE-like Monthly Gridded Averages (ES-4G) (5 of 8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
Albedo (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	0 .. 1	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky LW Flux (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	50 .. 400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky SW Flux (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	W m^{-2}	0 .. 1400	10368	16	3
Spares	4	N/A	N/A	166	8	10371
Clear Sky Albedo (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	0 .. 1	10368	16	3
Spares	4	N/A	N/A	166	8	10371

Total Meta Bits/File:	TBD
Total Data Bits/Record:	167936
Total Records/File 2:	342
Total Data Bits/File 2:	57434112
Total Bits/File 2:	57434112

Table B-4. ERBE-like Monthly Gridded Averages (ES-4G) (6 of 8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
ES_4G_2.5-deg_Regional_8-bit_Data (File 3)						
Number of Observations_Daily						
LW Flux (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Number of Observations	3	hour	0..24	10368	8	3
Spares	4	N/A	N/A	295	8	10371
SW Flux (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Number of Observations	3	hour	0..24	10368	8	3
Spares	4	N/A	N/A	295	8	10371
Clear Sky LW Flux (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Number of Observations	3	hour	0..24	10368	8	3
Spares	4	N/A	N/A	295	8	10371
Clear Sky SW Flux (31 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Number of Observations	3	hour	0..24	10368	8	3
Spares	4	N/A	N/A	295	8	10371
Number of Observations_Hourly						
LW Flux (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Number of Observations	3	day	0..31	10368	8	3
Spares	4	N/A	N/A	295	8	10371
SW Flux (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Number of Observations	3	day	0..31	10368	8	3
Spares	4	N/A	N/A	295	8	10371
Clear Sky LW Flux (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Number of Observations	3	day	0..31	10368	8	3
Spares	4	N/A	N/A	295	8	10371
Clear Sky SW Flux (24 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Number of Observations	3	day	0..31	10368	8	3
Spares	4	N/A	N/A	295	8	10371
Geotype						
Geotype_Instances						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Geotype of Region	3	N/A	0 .. 5	10368	8	3
Spares	4	N/A	N/A	295	8	10371

Total Meta Bits/File:	TBD
Total Data Bits/Record:	86016
Total Records/File 3:	221
Total Data Bits/File 3:	19009536
Total Bits/File 3:	19009536

Table B-4. ERBE-like Monthly Gridded Averages (ES-4G) (7 of 8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
ES_4G_Nested_Zonal_Global_data (File 4)						
(Same parameters as in 2.5-deg Regional Data Record)						
Nested_5.0-deg_Regional_Data						
32-bit_Data (87 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	N/A	N/A	2592	32	3
Spares	4	N/A	N/A	292	8	2595
16-bit_Data (342 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	N/A	2592	16	3
Spares	4	N/A	N/A	358	8	2595
8-bit_Data (221 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Monthly Averages	3	N/A	N/A	2592	8	3
Spares	4	N/A	N/A	391	8	2595
Nested_10.0-deg_Regional_Data						
32-bit_Data (87 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	N/A	N/A	648	32	3
Spares	4	N/A	N/A	388	8	651
16-bit_Data (342 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	N/A	648	16	3
Spares	4	N/A	N/A	150	8	651
8-bit_Data (221 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Monthly Averages	3	N/A	N/A	648	8	3
Spares	4	N/A	N/A	287	8	651
2.5-deg_Zonal_Data						
32-bit_Data (87 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	N/A	N/A	72	32	3
Spares	4	N/A	N/A	132	8	75
16-bit_Data (342 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	N/A	72	16	3
Spares	4	N/A	N/A	278	8	75
8-bit_Data (221 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Monthly Averages	3	N/A	N/A	72	8	3
Spares	4	N/A	N/A	351	8	75
5.0-deg_Zonal_Data						
32-bit_Data (87 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	N/A	N/A	36	32	3
Spares	4	N/A	N/A	276	8	39

Table B-4. ERBE-like Monthly Gridded Averages (ES-4G) (8 of 8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
16-bit_Data (342 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	N/A	36	16	3
Spares	4	N/A	N/A	350	8	39
8-bit_Data (221 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Monthly Averages	3	N/A	N/A	36	8	3
Spares	4	N/A	N/A	387	8	39
10.0-deg_Zonal_Data						
32-bit_Data (87 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	N/A	N/A	18	32	3
Spares	4	N/A	N/A	348	8	21
16-bit_Data (342 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	N/A	18	16	3
Spares	4	N/A	N/A	386	8	21
8-bit_Data (221 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Monthly Averages	3	N/A	N/A	18	8	3
Spares	4	N/A	N/A	405	8	21
Global_Data						
32-bit_Data (87 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	32	2
Monthly Averages	3	N/A	N/A	3	32	3
Spares	4	N/A	N/A	408	8	6
16-bit_Data (342 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	16	2
Monthly Averages	3	N/A	N/A	3	16	3
Spares	4	N/A	N/A	416	8	6
8-bit_Data (221 records)						
Data Description	1	N/A	N/A	1	640	1
Scale Factor	2	N/A	N/A	1	8	2
Monthly Averages	3	N/A	N/A	3	8	3
Spares	4	N/A	N/A	420	8	6

Total Meta Bits/File:	TBD
Maximum Data Bits/Record:	86016
Total Records/File 4:	3900
Total Data Bits/File 4:	47124480
Total Bits/File 4:	47124480
Total Bits on ES-4G	**152788992**

Appendix C

Nomenclature

Acronyms

ADEOS	Advanced Earth Observing System
ADM	Angular Distribution Model
AIRS	Atmospheric Infrared Sounder (EOS-AM)
AMSU	Advanced Microwave Sounding Unit (EOS-PM)
APD	Aerosol Profile Data
APID	Application Identifier
ARESE	ARM Enhanced Shortwave Experiment
ARM	Atmospheric Radiation Measurement
ASOS	Automated Surface Observing Sites
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTEX	Atlantic Stratocumulus Transition Experiment
ASTR	Atmospheric Structures
ATBD	Algorithm Theoretical Basis Document
AVG	Monthly Regional, Average Radiative Fluxes and Clouds (CERES Archival Data Product)
AVHRR	Advanced Very High Resolution Radiometer
BDS	Bidirectional Scan (CERES Archival Data Product)
BRIE	Best Regional Integral Estimate
BSRN	Baseline Surface Radiation Network
BTD	Brightness Temperature Difference(s)
CCD	Charge Coupled Device
CCSDS	Consultative Committee for Space Data Systems
CEPEX	Central Equatorial Pacific Experiment
CERES	Clouds and the Earth’s Radiant Energy System
CID	Cloud Imager Data
CLAVR	Clouds from AVHRR
CLS	Constrained Least Squares
COPRS	Cloud Optical Property Retrieval System
CPR	Cloud Profiling Radar
CRH	Clear Reflectance, Temperature History (CERES Archival Data Product)
CRS	Single Satellite CERES Footprint, Radiative Fluxes and Clouds (CERES Archival Data Product)
DAAC	Distributed Active Archive Center
DAC	Digital-Analog Converter
DAO	Data Assimilation Office

DB	Database
DFD	Data Flow Diagram
DLF	Downward Longwave Flux
DMSP	Defense Meteorological Satellite Program
EADM	ERBE-like Albedo Directional Model (CERES Input Data Product)
ECA	Earth Central Angle
ECLIPS	Experimental Cloud Lidar Pilot Study
ECMWF	European Centre for Medium-Range Weather Forecasts
EDDB	ERBE-like Daily Data Base (CERES Internal Data Product)
EID6	ERBE-like Internal Data Product 6 (CERES Internal Data Product)
EID9	ERBE-like Internal Data Product 9 (CERES Internal Data Product)
EOS	Earth Observing System
EOSDIS	Earth Observing System Data Information System
EOS-AM	EOS Morning Crossing Mission
EOS-PM	EOS Afternoon Crossing Mission
ENSO	El Niño/Southern Oscillation
ENVISAT	Environmental Satellite
EPHANC	Ephemeris and Ancillary (CERES Input Data Product)
ERB	Earth Radiation Budget
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
ESA	European Space Agency
ES4	ERBE-like S4 Data Product (CERES Archival Data Product)
ES4G	ERBE-like S4G Data Product (CERES Archival Data Product)
ES8	ERBE-like S8 Data Product (CERES Archival Data Product)
ES9	ERBE-like S9 Data Product (CERES Archival Data Product)
FLOP	Floating Point Operation
FIRE	First ISCCP Regional Experiment
FIRE II IFO	First ISCCP Regional Experiment II Intensive Field Observations
FOV	Field of View
FSW	Hourly Gridded Single Satellite Fluxes and Clouds (CERES Archival Data Product)
FTM	Functional Test Model
GAC	Global Area Coverage (AVHRR data mode)
GAP	Gridded Atmospheric Product (CERES Input Data Product)
GCIP	GEWEX Continental-Phase International Project
GCM	General Circulation Model
GEBA	Global Energy Balance Archive
GEO	ISSCP Radiances (CERES Input Data Product)
GEWEX	Global Energy and Water Cycle Experiment

GLAS	Geoscience Laser Altimetry System
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
HBTM	Hybrid Bispectral Threshold Method
HIRS	High-Resolution Infrared Radiation Sounder
HIS	High-Resolution Interferometer Sounder
ICM	Internal Calibration Module
ICRCCM	Intercomparison of Radiation Codes in Climate Models
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
IES	Instrument Earth Scans (CERES Internal Data Product)
IFO	Intensive Field Observation
INSAT	Indian Satellite
IOP	Intensive Observing Period
IR	Infrared
IRIS	Infrared Interferometer Spectrometer
ISCCP	International Satellite Cloud Climatology Project
ISS	Integrated Sounding System
IWP	Ice Water Path
LAC	Local Area Coverage (AVHRR data mode)
LaRC	Langley Research Center
LBC	Laser Beam Ceilometer
LBTM	Layer Bispectral Threshold Method
Lidar	Light Detection and Ranging
LITE	Lidar In-Space Technology Experiment
Lowtran 7	Low-Resolution Transmittance (Radiative Transfer Code)
LW	Longwave
LWP	Liquid Water Path
MAM	Mirror Attenuator Mosaic
MC	Mostly Cloudy
MCR	Microwave Cloud Radiometer
METEOSAT	Meteorological Operational Satellite (European)
METSAT	Meteorological Satellite
MFLOP	Million FLOP
MIMR	Multifrequency Imaging Microwave Radiometer
MISR	Multiangle Imaging Spectroradiometer
MLE	Maximum Likelihood Estimate
MOA	Meteorology Ozone and Aerosol
MODIS	Moderate-Resolution Imaging Spectroradiometer

MSMR	Multispectral, multiresolution
MTSA	Monthly Time and Space Averaging
MWH	Microwave Humidity
MWP	Microwave Water Path
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
NIR	Near Infrared
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
OLR	Outgoing Longwave Radiation
OPD	Ozone Profile Data (CERES Input Data Product)
OV	Overcast
PC	Partly Cloudy
POLDER	Polarization of Directionality of Earth's Reflectances
PRT	Platinum Resistance Thermometer
PSF	Point Spread Function
PW	Precipitable Water
RAPS	Rotating Azimuth Plane Scan
RPM	Radiance Pairs Method
RTM	Radiometer Test Model
SAB	Sorting by Angular Bins
SAGE	Stratospheric Aerosol and Gas Experiment
SARB	Surface and Atmospheric Radiation Budget Working Group
SDCD	Solar Distance Correction and Declination
SFC	Hourly Gridded Single Satellite TOA and Surface Fluxes (CERES Archival Data Product)
SHEBA	Surface Heat Budget in the Arctic
SPECTRE	Spectral Radiance Experiment
SRB	Surface Radiation Budget
SRBAVG	Surface Radiation Budget Average (CERES Archival Data Product)
SSF	Single Satellite CERES Footprint TOA and Surface Fluxes, Clouds
SSMI	Special Sensor Microwave Imager
SST	Sea Surface Temperature
SURFMAP	Surface Properties and Maps (CERES Input Product)
SW	Shortwave
SWICS	Shortwave Internal Calibration Source

SYN	Synoptic Radiative Fluxes and Clouds (CERES Archival Data Product)
SZA	Solar Zenith Angle
THIR	Temperature/Humidity Infrared Radiometer (Nimbus)
TIROS	Television Infrared Observation Satellite
TISA	Time Interpolation and Spatial Averaging Working Group
TMI	TRMM Microwave Imager
TOA	Top of the Atmosphere
TOGA	Tropical Ocean Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
TSA	Time-Space Averaging
UAV	Unmanned Aerospace Vehicle
UT	Universal Time
UTC	Universal Time Code
VAS	VISSR Atmospheric Sounder (GOES)
VIRS	Visible Infrared Scanner
VISSR	Visible and Infrared Spin Scan Radiometer
WCRP	World Climate Research Program
WG	Working Group
Win	Window
WN	Window
WMO	World Meteorological Organization
ZAVG	Monthly Zonal and Global Average Radiative Fluxes and Clouds (CERES Archival Data Product)

Symbols

A	atmospheric absorptance
$B_\lambda(T)$	Planck function
C	cloud fractional area coverage
CF_2Cl_2	dichlorofluorocarbon
$CFCl_3$	trichlorofluorocarbon
CH_4	methane
CO_2	carbon dioxide
D	total number of days in the month
D_e	cloud particle equivalent diameter (for ice clouds)
E_o	solar constant or solar irradiance
F	flux
f	fraction

G_a	atmospheric greenhouse effect
g	cloud asymmetry parameter
H_2O	water vapor
I	radiance
i	scene type
m_i	imaginary refractive index
$\hat{N}$	angular momentum vector
N_2O	nitrous oxide
O_3	ozone
P	point spread function
p	pressure
Q_a	absorption efficiency
Q_e	extinction efficiency
Q_s	scattering efficiency
R	anisotropic reflectance factor
r_E	radius of the Earth
r_e	effective cloud droplet radius (for water clouds)
r_h	column-averaged relative humidity
S_o	summed solar incident SW flux
S_o'	integrated solar incident SW flux
T	temperature
T_B	blackbody temperature
t	time or transmittance
W_{liq}	liquid water path
w	precipitable water
$\hat{x}_o$	satellite position at t_o
x, y, z	satellite position vector components
$\dot{x}, \dot{y}, \dot{z}$	satellite velocity vector components
z	altitude
z_{top}	altitude at top of atmosphere
α	albedo or cone angle
β	cross-scan angle
γ	Earth central angle
γ_{at}	along-track angle
γ_{ct}	cross-track angle
δ	along-scan angle
ε	emittance
Θ	colatitude of satellite
θ	viewing zenith angle

θ_o	solar zenith angle
λ	wavelength
μ	viewing zenith angle cosine
μ_o	solar zenith angle cosine
ν	wave number
ρ	bidirectional reflectance
τ	optical depth
$\tau_{aer}(p)$	spectral optical depth profiles of aerosols
$\tau_{H_2O\lambda}(p)$	spectral optical depth profiles of water vapor
$\tau_{O_3}(p)$	spectral optical depth profiles of ozone
Φ	longitude of satellite
ϕ	azimuth angle
$\tilde{\omega}_o$	single-scattering albedo

Subscripts:

c	cloud
cb	cloud base
ce	cloud effective
cld	cloud
cs	clear sky
ct	cloud top
ice	ice water
lc	lower cloud
liq	liquid water
s	surface
uc	upper cloud
λ	spectral wavelength

Units

AU	astronomical unit
cm	centimeter
cm-sec^{-1}	centimeter per second
count	count
day	day, Julian date
deg	degree
deg-sec^{-1}	degree per second
DU	Dobson unit
erg-sec^{-1}	erg per second
fraction	fraction (range of 0–1)
g	gram

g-cm^{-2}	gram per square centimeter
g-g^{-1}	gram per gram
g-m^{-2}	gram per square meter
h	hour
hPa	hectopascal
K	Kelvin
kg	kilogram
kg-m^{-2}	kilogram per square meter
km	kilometer
km-sec^{-1}	kilometer per second
m	meter
mm	millimeter
μm	micrometer, micron
N/A	not applicable, none, unitless, dimensionless
ohm-cm^{-1}	ohm per centimeter
percent	percent (range of 0–100)
rad	radian
rad-sec^{-1}	radian per second
sec	second
sr^{-1}	per steradian
W	watt
W-m^{-2}	watt per square meter
W-m^{-2}sr^{-1}	watt per square meter per steradian
W-m^{-2}sr^{-1}μm^{-1}	watt per square meter per steradian per micrometer