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

Algorithm Theoretical Basis Document

ERBE-Like Inversion to Instantaneous TOA Flux

(Subsystem 2.0)

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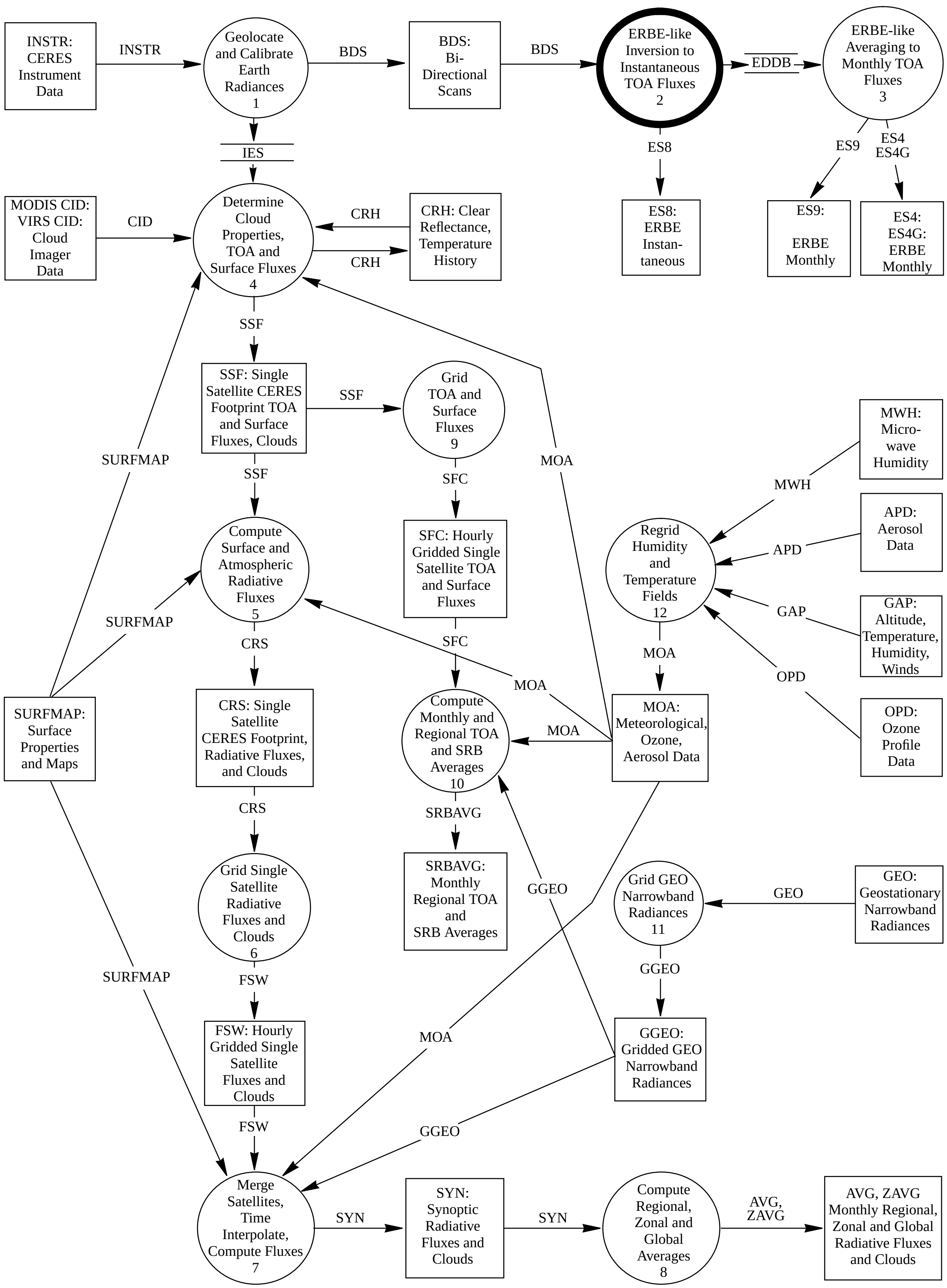
CERES Top Level Data Flow Diagram



Abstract

This Inversion Subsystem converts filtered radiometric measurements in engineering units to instantaneous flux estimates at the top-of-the-atmosphere (TOA). The basis for this procedure is the ERBE Data Management System which produced TOA fluxes from the ERBE scanning radiometers aboard the ERBS, NOAA-9, and NOAA-10 satellites over a 5-year period from November 1984 to February 1990 (Barkstrom 1984; Barkstrom and Smith 1986). The ERBE Inversion Subsystem is a mature set of algorithms that has been well documented and tested. The strategy for the ERBE-like products is to process the CERES data through the same processing system as ERBE with only minimal changes necessary to adapt to the CERES instrument characteristics. This system will be coded and operational at launch. An overview of the ERBE Inversion Subsystem is given by Smith et al. (1986).

2.1 INTRODUCTION

The ERBE-like Inversion Subsystem consists of a number of algorithms which are described in the following sections. The Spectral Correction Algorithm corrects the filtered radiances to unfiltered radiances. The observed scene type is then identified with the Maximum Likelihood Estimation (MLE) technique. Once the scene type is known, the Radiance-to-Flux Conversion is accomplished with the Angular Distribution Models (ADM). The individual flux estimates are recorded in the ERBE-like product in the same order in which they are measured, that is, they are time ordered and not spatially ordered along the groundtrack (see subsection 4.4.2.4). Finally, the Regional Averaging Algorithm produces regional fluxes from the instantaneous fluxes. At many points during the processing Quality Checks are performed to eliminate erroneous results.

The CERES Validation Plans are currently being developed. Following a peer review in late 1996, the Validation Plans will be made available on the WWW in the Summer of 1997.

2.2 ALGORITHM DESCRIPTION

2.2.1 Spectral Correction

The Spectral Correction Algorithm corrects the radiometric measurements for the imperfect spectral response of the optical path in the instrument. Radiation from the scene is collected and focused by primary and secondary mirrors, passes through the filter (for the shortwave and window channels), impinges on the detector, and causes a signal which is sampled and processed by the electronics, resulting in a filtered measurement (see Subsystem 1.0). To correct this filtered signal, we need to know the spectral response of the individual channels and the spectral nature of the observed scene. The objective is to determine the reflected (or shortwave) radiation below 5 μm, the emitted (or longwave) radiation above 5 μm and the window radiation from 8 to 12 μm.

We model the “filtered” scanner measured radiance as

$$I_F^j = \int_0^\infty S_\lambda^j I_\lambda d\lambda + \varepsilon^j \qquad j = SW, TOT, WN$$

where λ is wavelength in μm; I_λ is the spectral radiance incident on the instrument in $Wm^{-2}sr^{-1}\mu m^{-1}$; S_λ is the normalized spectral response of the instrument (Figure 1-2) such that $0 \le S_\lambda \le 1$; ε is the instrument error in $Wm^{-2}sr^{-1}$ with mean 0 and variance σ_ε^2 which results from count conversion error, instrument noise, and any instrument error except spectral dependance effects; and j denotes the shortwave, total, or window scanner channel. We desire to estimate the "unfiltered" scanner radiances which are defined as

$$I^i = \int_0^\infty C_\lambda^i I_\lambda d\lambda \qquad i = SW, LW, WN$$

where

$$C_\lambda^{SW} = \begin{cases} 1 & (0 \le \lambda < 5\mu m) \\ 0 & (\text{Otherwise}) \end{cases}$$

$$C_\lambda^{LW} = \begin{cases} 0 & (5 \le \lambda \le 50\mu m) \\ 1 & (\text{Otherwise}) \end{cases}$$

$$C_\lambda^{WN} = \begin{cases} 1 & (8\mu m \le \lambda \le 12\mu m) \\ 0 & (\text{Otherwise}) \end{cases}$$

Let us consider I_λ and ε as random variables so that both the filtered and unfiltered radiances are random variables. We desire to estimate the unfiltered radiances from the filtered radiances given the statistics of I_λ and ε. For simplicity, define the random vector of filtered radiances Y and the random vector of unfiltered radiances X as

$$Y = \begin{bmatrix} I_F^{SW} \\ I_F^{TOT} \\ I_F^{WN} \end{bmatrix} \qquad X = \begin{bmatrix} I^{SW} \\ I^{LW} \\ I^{WN} \end{bmatrix}$$

We will assume a linear estimator $\hat{X} = BY$ and choose to minimize the diagonal terms of the matrix $E[(\hat{X} - X)(\hat{X} - X)^T]$ where E[x] is the statistical expectation operator. This estimator is called the minimum mean square error estimator. From the Gauss-Markoff theorem (Liebelt 1967) we have

$$\hat{X} = E[XY^T](E[YY^T])^{-1}Y$$

We will define the quantities $E[XY^T]$ and $E[YY^T]$ empirically from data. The general elements are

$$E[X^iY^j] = \int_0^\infty\int_0^\infty C^i_\lambda S^j_\lambda E[I_\lambda I_{\lambda'}]d\lambda d\lambda' \equiv \overline{X^iY^j} \qquad \begin{array}{l} i = SW, LW, WN \\ j = SW, TOT, WN \end{array}$$

$$E[Y^rY^s] = \int_0^\infty\int_0^\infty S^r_\lambda S^s_\lambda E[I_\lambda I_{\lambda'}]d\lambda d\lambda' \equiv \overline{Y^rY^s} + \sigma^2_{rs} \qquad r, s = SW, TOT, WN$$

We have modeled I_λ as a random variable (or random function) over the ensemble of all possible scenes. Let us assume knowledge of a finite number (say N) of these possible scenes and approximate the expected value with a simple weighted average or

$$E[I_\lambda I_{\lambda'}] \approx \sum_{k=1}^{N} p^k I^k_\lambda I^k_{\lambda'} \equiv \overline{I_\lambda I_{\lambda'}}$$

where p^k is the probability of I^k_λ and $\sum_k p^k = 1$. Thus, we have

$$E[X^iY^j] \approx \int_0^\infty\int_0^\infty C^i_\lambda S^j_\lambda \overline{I_\lambda I_{\lambda'}}d\lambda d\lambda' \equiv \overline{X^iY^j} \qquad \begin{array}{l} i = SW, LW, WN \\ j = SW, TOT, WN \end{array}$$

$$E[Y^rY^s] \approx \int_0^\infty\int_0^\infty S^r_\lambda S^s_\lambda \overline{I_\lambda I_{\lambda'}}d\lambda d\lambda' \equiv \overline{Y^rY^s} + \sigma^2_{rs} \qquad r, s = SW, TOT, WN$$

The spectral correction coefficients are mean values and thus introduce error into the process. This error is minimized by determining different coefficients for ocean, land, desert, snow, and cloud over three latitude ranges. In addition, the spectra shift with viewing zenith, solar zenith, and relative azimuth angles so that the coefficients are also functions of these angles.

The scene must be identified before the radiances can be unfiltered. However, the scene identification algorithm requires unfiltered radiances to determine the scene. This problem is overcome by first unfiltering the radiances based on the surface type and a global a priori cloud cover. This global unfiltering is within 5% of the true value. After the scene is identified, the unfiltered radiances are recomputed using the correct scene.

The spectral correction equations have been developed in general where all 3 channels affect each of the 3 unfiltered radiances. We have also developed spectral correction coefficients for subsets of the three input channels. For ERBE-like processing, the shortwave and longwave radiances will be defined by the shortwave and total channels with no effect from the window channel. This unfiltering more closely resembles the ERBE spectral correction algorithm which relied almost entirely on the total and shortwave channels with only minimal effect from the non-flat longwave channel. For ERBE-like processing, the unfiltered window radiance will depend on the window channel alone with no effect from the shortwave and total channels.

The Spectral Correction Algorithm has been used very successfully on the ERBE. The best references are Avis et al. (1984), Smith et al. (1986), and Green and Avis (1996).

2.2.2. Scene Identification

The unfiltered radiances are a direct measurement of radiance, while the desired product is radiative flux at the top of the atmosphere (TOA). Derivation of radiative flux using the scanner radiance observations then requires the use of ADM's to correct for the anisotropy of the radiation field. Two of the major causes of variability in the ADM's are change in geographic surface type (ocean, land, etc.) and change in cloud conditions (variable cloud cover for example). The surface types can be handled using a static geographic map. Cloud conditions, however, require dynamic identification of the scene being viewed to achieve accurate flux estimates. Four basic cloud categories are defined which encompass all cloud conditions. These four types are clear (0%-5% cloud cover), partly cloudy (5%-50% cloud cover), mostly cloudy (50%-95% cloud cover), and overcast (95%-100% cloud cover). Surface type and cloud condition are combined to give the 12 ERBE scene types given in Table 2-1:.

Table 2-1: ERBE Scene Types

Index	Scene Types
1	Clear ocean
2	Clear land
3	Clear snow
4	Clear desert
5	Clear land-ocean mix (coastal)
6	Partly cloudy over ocean
7	Partly cloudy over land or desert
8	Partly cloudy over land-ocean mix
9	Mostly cloudy over ocean
10	Mostly cloudy over land or desert
11	Mostly cloudy over land-ocean mix
12	Overcast

The scene identification procedure first classifies the underlying surface by its geographic type: land, ocean, snow, desert, or land-ocean mix for $2.5^o \times 2.5^o$ regions. The cloud class for a given measurement pair (shortwave and longwave radiances) is selected by comparing the measurement pair to a priori statistics developed from a classification of Nimbus-7 ERB scanning radiometer data. The cloud class chosen is the class which most probably produced the measurements. This classification method is known as the Maximum Likelihood Estimation (MLE) and is fully documented by Wielicki and Green (1989).

2.2.3. Radiance-to-Flux Conversion

We define the outgoing radiance I at the TOA as

$$I = \pi^{-1}FR$$

where F is the flux in Wm^{-2} and R is the Angular Distribution Model (ADM). To convert satellite radiance to flux at the TOA, we solve for F or

$$\hat{F} = \frac{\pi I}{R}$$

where I is the unfiltered measured radiance and R is a numerical model of the anisotropy evaluated at the viewing and solar geometry. A complete set of ADM's for the 12 ERBE scene types has been developed from Nimbus-7 data for both shortwave and longwave radiance and are given by Suttles et al. (1988, 1989).

2.2.4. Spatial Averaging

For each scanner measurement of radiance, the instantaneous flux is computed. These flux values are then averaged to produce estimates of the instantaneous regional fluxes. In the ERBE data analysis, all measurements whose center points lie within a $2.5^{o} \times 2.5^{o}$ region are averaged with equal weight to produce the estimate of regional average flux, as has been done previously in analyses of the Earth radiation budget. The regional averages will be determined for both the fixed azimuth plane scan (FAP) and the rotating azimuth plane scan (RAP). In forming the estimate of the regional average flux one encounters errors due to the spatial sampling or coverage problem. This spatial sampling problem has been studied by Smith and Bess (1978) and Smith et al. (1983).

2.3 IMPLEMENTATION ISSUES

2.3.1 Quality Checks

Restrictions are imposed on the inversion processing to eliminate sensitive areas of high errors. Measurements with viewing zenith angles greater than 70^{o} are not processed. Also, measurements in areas where the ADM anisotropy exceeds 2.0 (or twice Lambertian) are not inverted.

A number of quality control checks are performed. Each measurement is associated with a flag which is set to "good" or "bad". If the measurement is flagged "bad" for any reason by any subsystem, it is not processed. If the measurement is flagged "good", it is processed and then tested. The TOA flux estimates are replaced by default values if the estimate of albedo is outside the range 0.02 - 1.00 or the estimate of longwave flux is outside the range 50 - 400 Wm^{-2}. The MLE selects the most probable scene type. When it is 8 standard deviations away from its a priori expectation, the scene identification is considered unreliable and the measurement is not inverted to the TOA.

2.4 REFERENCES

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Appendix A

Input Data Products

ERBE-like Inversion to Instantaneous TOA Fluxes (Subsystem 2.0)

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 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 A-1. Input Products Summary

Product Code		Name	Type	Frequency	Size, MB	Monthly Size, MB
CERES	EOSDIS					
BDS	CER01	BiDirectional Scan	Archival	1/Day	710.92	22039

Bidirectional Scan (BDS)

The BDS data product is an archival product containing level 1b CERES scanner data obtained for a 24 hour period. All science scan modes are included in the BDS, including the fixed and rotating azimuth scan modes that perform normal earth, internal calibration, and short scan elevation profiles. The BDS product includes samples taken for all 660 measurements (including space looks and internal calibration views).

The BDS includes the raw (unconverted) science and instrument data from the Level 0 input file (excluding Level 0 header and footer data) as well as the converted science and instrument data. The BDS also contains additional data not found in the Level 0 input file. This additional data is composed primarily of converted satellite position and velocity data, celestial data, and converted digital data.

All of the BDS data use Hierarchical Data Format (HDF) structures such as Vdata and Scientific Data Sets (SDSs). Metadata for the BDS is implemented using the ECS Toolkit metadata routines, which are based on HDF Annotations.

The general composition of a BDS in terms of HDF components is as follows:

1. Metadata	Annotations
2. Unconverted Science Data	SDS(s)
3. Unconverted Instrument Data	Vdata(s)
4. Converted Science Data	SDS(s)
5. Converted Instrument Data	Vdata(s)
6. Satellite/Celestial Data	Vdata(s)

A complete and more detailed listing of the data parameters for this product can be found in the subsequent figure(s) and tables of this section.

Level: 1b
Type: Archival
Frequency: 1/Day

Portion of Globe Covered
File: Satellite Swath
Record: N/A

Time Interval Covered
File: 24 hours
Record: Single 6.6 second packet

Portion of Atmosphere Covered
File: Satellite Altitude

BDS Metadata - TBD

BDS Scientific Data Sets

Every Scientific Data Set (SDS) in the BDS file, with exception of the SDS for Julian Times and the SDS for Unconverted Digital Data, represents a time ordered collection of data where each row in the SDS corresponds to a packet of data, and each column corresponds to a single sample within a packet.

(Note: n = the number of packets/scan lines processed)

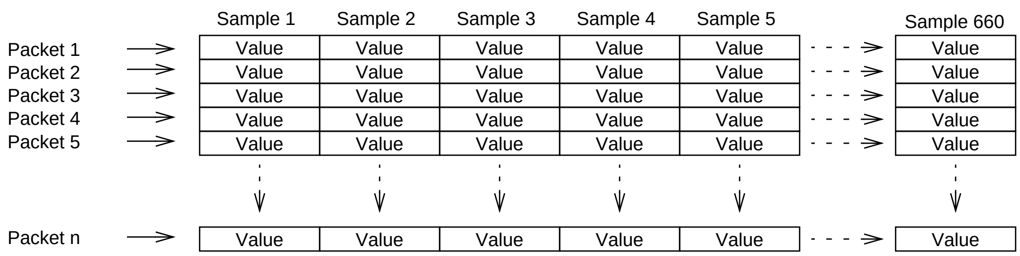

Table B-1 summarizes the contents of each SDS contained within the BDS file. For additional information regarding HDF Scientific Data Sets, consult the HDF User's Guide[1].

Table A-2. BDS SDS Summary

SDS Name	HDF Rank	Rows	Columns	Data Type	Range	Units	~Nominal Size (MB)*
Shortwave Detector Output	2	n	660	U16 Integer	0..4095	counts	16.45
Total Detector Output	2	n	660	U16 Integer	0..4095	counts	16.45
Window Detector Output	2	n	660	U16 Integer	0..4095	counts	16.45
Elevation Position Count	2	n	660	U16 Integer	0..4095	counts	16.45
Azimuth Position Count	2	n	660	U16 Integer	0..4095	counts	16.45
Raw Digital Status Measurement	2	n	185	U16 Integer	Table B-2	N/A	4.62
Shortwave Filtered Radiances	2	n	660	32 Bit Float	-10.0..510.0	Wm^{-2}sr^{-1}	32.96
Total Filtered Radiances	2	n	660	32 Bit Float	0.0..700.0	Wm^{-2}sr^{-1}	32.96
Window Filtered Radiances	2	n	660	32 Bit Float	0.0..50.0	Wm^{-2}sr^{-1}	32.96
Colatitude of FOV at TOA	2	n	660	64 Bit Float	0.0..180.0	degrees	65.92
Longitude of FOV at TOA	2	n	660	64 Bit Float	0.0..360.0	degrees	65.92
Viewing Zenith at TOA	2	n	660	64 Bit Float	0.0..90.0	degrees	65.92
Solar Zenith at TOA	2	n	660	64 Bit Float	0.0..180.0	degrees	65.92
Relative Azimuth at TOA	2	n	660	64 Bit Float	0.0..360.0	degrees	65.92

1. Version 4.0, February 1996 from NCSA

Table A-2. BDS SDS Summary (Continued)

SDS Name	HDF Rank	Rows	Columns	Data Type	Range	Units	~Nominal Size (MB)*
Converted Elevation Angles	2	n	660	64 Bit Float	0.0..180.0	degrees	65.92
Converted Azimuth Angles	2	n	660	64 Bit Float	0.0..270.0	degrees	65.92
Quality Flags	2	n	660	U32 Integer	Table B-3	N/A	32.96
Julian Time Indices	2	n	2	64 Bit Float	N/A	N/A	0.20
SDS TOTAL SIZE							**680.35**

* - n = 13091

BDS Vdatas

HDF Vdatas contained in the BDS represent tables of records which typically contain instrument housekeeping data. As with the BDS Scientific Data Sets, each record in a Vdata is associated with a single packet. Associations between Vdatas and SDSs are mapped by matching row numbers and record numbers. For example, all data for packet no. 15 can be will contained in row 15 of all SDSs and record 15 of all Vdatas contained in the BDS[1]. Table B-2 contains summary information for all of the BDS Vdatas.

Table A-3. BDS Vdata Summary

Vdata Name	Total Records	Fields Per Record	Record Size (bytes)	Fields	~Nominal Size (MB)*
Temperature Counts	n	39	450	See Table B-5	5.62
Voltage and Torque Counts	n	24	180	See Table B-6	2.25
Position Counts	n	12	528	See Table B-7	6.70
Temperatures	n	35	708	See Table B-8	8.84
Voltages and Torques	n	23	348	See Table B-9	4.35
Satellite Positions	n	20	156	See Table B-10	1.95
Converted Digital Data	n	18	75	See Table B-11	0.94
VDATA TOTAL SIZE					30.65

* - n = 13091

1. HDF row and record are actually 0 based, so the corresponding data for packet n would be contained in row n-1 of each SDS and record n-1 of each Vdata. For additional, information consult the HDF User's Guide.

Table A-4. Digital Data Word Definitions

Word	Parameter Name	Bits (MSB = 0)
0	Instrument Mode Sequence Number	0..4
	Instrument Previous Mode Sequence Number	5..9
	Mode Sequence Changed By	10..12
	Mode Sequence Has Changed	13..14
	Spare Bit	15
1	Sequence Command Index	0..4
	Sequence Execution Status	5..7
	Sequence Time to Next Command	8..15
2	Spare Word	0..15
3	Spare Word	0..15
4	Spare Word	0..15
5	Spare Word	0..15
6	Spare Word	0..15
7	Instrument Command Counter	0..15
8	Instrument Command Main 1	0..15
9	Instrument Command Parameter 1	0..15
10	Instrument Command Sample Number 1	0..9
	Instrument Command Status 1	10..14
	Instrument Command Source 1	15
11	Instrument Command Main 2	0..15
12	Instrument Command Parameter 2	0..15
13	Instrument Command Sample Number 2	0..9
	Instrument Command Status 2	10..14
	Instrument Command Source 2	15
14	Instrument Command Main 3	0..15
15	Instrument Command Parameter 3	0..15
16	Instrument Command Sample Number 3	0..9
	Instrument Command Status 3	10..14
	Instrument Command Source 3	15
17	Instrument Command Main 4	0..15
18	Instrument Command Parameter 4	0..15
19	Instrument Command Sample Number 4	0..9
	Instrument Command Status 4	10..14
	Instrument Command Source 4	15
20	Instrument Command Main 5	0..15
21	Instrument Command Parameter 5	0..15
22	Instrument Command Sample Number 5	0..9
	Instrument Command Status 5	10..14
	Instrument Command Source 5	15
23	Instrument Command Main 6	0..15
24	Instrument Command Parameter 6	0..15
25	Instrument Command Sample Number 6	0..9
	Instrument Command Status 6	10..14
	Instrument Command Source 6	15
26	Instrument Command Main 7	0..15
27	Instrument Command Parameter 7	0..15
28	Instrument Command Sample Number 7	0..9
	Instrument Command Status 7	10..14
	Instrument Command Source 7	15
29	Instrument Command Main 8	0..15

Table A-4. Digital Data Word Definitions (Continued)

Word	Parameter Name	Bits (MSB = 0)
30	Instrument Command Parameter 8	0..15
31	Instrument Command Sample Number 8	0..9
	Instrument Command Status 8	10..14
	Instrument Command Source 8	15
32	Instrument Error Counter	0..15
33	Instrument Error Sample Number 1	0..9
	Instrument Error Type 1	10..15
34	Instrument Error Sample Number 2	0..9
	Instrument Error Type 2	10..15
35	Instrument Error Sample Number 3	0..9
	Instrument Error Type 3	10..15
36	Instrument Error Sample Number 4	0..9
	Instrument Error Type 4	10..15
37	Instrument Error Sample Number 5	0..9
	Instrument Error Type 5	10..15
38	Instrument Error Sample Number 6	0..9
	Instrument Error Type 6	10..15
39	Instrument Error Sample Number 7	0..9
	Instrument Error Type 7	10..15
40	Instrument Error Sample Number 8	0..9
	Instrument Error Type 8	10..15
41	Spare Word	0..15
42	Spare Word	0..15
43	Spare Word	0..15
44	Spare Word	0..15
45	Spare Word	0..15
46	Total Bridge Balance Control Status	0..2
	Total Bridge Balance DAC Update Status Value	3
	Total Bridge Balance Reset Counter	4..8
	Spare Bits	9..15
47	Total Spacelook Average	0..11
	Spare Bits	12..15
48	Total Bridge Balance DAC Coarse Value	0..11
	Spare Bits	12..15
49	Total Bridge Balance DAC Fine Value	0..11
	Spare Bits	12..15
50	SW Bridge Balance Control Status	0..2
	SW Bridge Balance DAC Update Status Value	3
	SW Bridge Balance Reset Counter	4..8
	Spare Bits	9..15
51	SW Spacelook Average	0..11
	Spare Bits	12..15
52	SW Bridge Balance DAC Coarse Value	0..11
	Spare Bits	12..15
53	SW Bridge Balance DAC Fine Value	0..11
	Spare Bits	12..15
54	LW Bridge Balance Control Status	0..2
	LW Bridge DAC Update Status Value	3
	LW Bridge Balance Reset Counter	4..8
	Spare Bits	9..15

Table A-4. Digital Data Word Definitions (Continued)

Word	Parameter Name	Bits (MSB = 0)
55	LW Spacelook Average	0..11
	Spare Bits	12..15
56	LW Bridge Balance DAC Coarse Value	0..11
	Spare Bits	12..15
57	LW Bridge Balance DAC Fine Value	0..11
	Spare Bits	12..15
58	Bridge Balance Spacelook Start Sample Number	0..9
	Spare Bits	10..15
59	Bridge Balance Spacelook End Sample Number	0..9
	Spare Bits	10..15
60	Bridge Balance DAC Update Sample Number	0..9
	Spare Bits	10..15
61	Bridge Balance Window High Value	0..11
	Spare Bits	12..15
62	Bridge Balance Window Low Value	0..11
	Spare Bits	12..15
63	Bridge Balance Window Setpoint Value	0..11
	Spare Bits	12..15
64	Total Detector Temperature Setpoint	0..11
	Total Detector Temperature Control Status	12
	Spare Bits	13..15
65	SW Detector Temperature Setpoint	0..11
	SW Detector Temperature Control Status	12
	Spare Bits	13..15
66	LW Detector Temperature Setpoint	0..11
	LW Detector Temperature Control Status	12
	Spare Bits	13..15
67	Blackbody Temperature Setpoint	0..11
	Blackbody Temperature Control Status	12
	Spare Bits	13..15
68	SWICS Intensity Level	0..1
	Spare Bits	2..15
69	Spare Word	0..15
70	Elevation Scan Mode	0..4
	Elevation On Deck Scan Mode	5..9
	Elevation Scan Status	10..12
	Elevation Motor Drive	13
	Elevation Encoder LED Intensity	14
	Elevation Stall	15
71	Elevation Offset Correction	0..15
72	Elevation Stall Error Threshold	0..15
73	Elevation Stall Count Threshold	0..9
	Spare Bits	10..15
74	Elevation Position Error Sample 1	0..15
75	Elevation Position Error Sample 2	0..15
76	Elevation Position Error Sample 3	0..15
77	Main Cover Command	0..3
	Main Cover Motion Status	4..7
	Main Cover Position Status	8..11
	Main Cover Sensor Active	12..13
	Spare Bits	14..15

Table A-4. Digital Data Word Definitions (Continued)

Word	Parameter Name	Bits (MSB = 0)
78	Main Cover Commanded Position	0..11
	Spare Bits	12..15
79	Main Cover Accumulated Lag Error Sensor 1	0..7
	Spare Bits	8..15
80	Main Cover Accumulated Lag Error Sensor 2	0..7
	Spare Bits	8..15
81	Main Cover Fixed Step Count	0..15
82	Main Cover Defined Closed Position	0..11
	Spare Bits	12..15
83	Main Cover Defined Open Position	0..11
	Spare Bits	12..15
84	Main Cover Defined Closed Margin	0..11
	Spare Bits	12..15
85	Main Cover Defined Open Margin	0..11
	Spare Bits	12..15
86	MAM Cover Command	0..3
	MAM Cover Motion Status	4..7
	MAM Cover Position Status	8..11
	MAM Cover Sensor Active	12..13
	Spare Bits	14..15
87	MAM Cover Commanded Position	0..11
	Spare Bits	12..15
88	Spare Word	0..15
89	Spare Word	0..15
90	MAM Cover Fixed Step Count	0..15
91	MAM Cover Defined Closed Position	0..11
	Spare Bits	12..15
92	MAM Cover Defined Open Position	0..11
	Spare Bits	12..15
93	MAM Cover Defined Closed Margin	0..11
	Spare Bits	12..15
94	MAM Cover Defined Open Margin	0..11
	Spare Bits	12..15
95	DAP Watchdog Boot Status	0
	DAP Watchdog Enable Status	1
	DAP PROM Power Status	2
	DAP Sample Clock Interrupt Occured	3..4
	Spare Bits	5..15
96	DA{ Scan Period Counter	0..15
97	DAP Memory Dump Start Address Offset	0..15
98	DAP Memory Dump Start Address Segment	0..15
99	DAP Memory Dump End Address Offset	0..15
100	DAP Memory Dump End Address Segment	0..15
101	DAP Packet Start Address Offset	0..15
102	DAP Packet Start Address Segment	0..15
103	DAP Address Changes Indicator	0..15
104	DAP Minimum Execution Time	0..15
105	DAP Minimum Sample Number	0..10
	Spare Bits	11..15
106	DAP Maximum Execution Time	0..15

Table A-4. Digital Data Word Definitions (Continued)

Word	Parameter Name	Bits (MSB = 0)
107	DAP Maximum Sample Number	0..10
	Spare Bits	11..15
108	DAP RAM Code Checksum	0..15
109	DAP ROM Code Checksum	0..15
110	Spare Word	0..15
111	Spare Word	0..15
112	Spare Word	0..15
113	Spare Word	0..15
114	Spare Word	0..15
115	Azimuth Mode	0..4
	Azimuth Motion Status	5
	Azimuth Direction Status	6
	Azimuth Position Status	7..10
	Azimuth Motor Drive Status	11
	Azimuth Encoder LED Status	12
	Azimuth Stall	13
	Spare Bits	14..15
116	Azimuth Defined Crosstrack Position	0..15
117	Azimuth Defined Fixed Position A	0..15
118	Azimuth Defined Fixed Position B	0..15
119	Azimuth Defined Fixed Solar Calibration Position	0..15
120	Azimuth Defined Fixed Cage Position	0..15
121	Azimuth Defined Fixed Position Spare 1	0..15
122	Azimuth Defined Fixed Position Spare 2	0..15
123	Azimuth Defined Fixed Position Spare 3	0..15
124	Azimuth Defined Normal Slew Rate	0..15
125	Azimuth Defined Asynchronous Scan Rate	0..15
126	Azimuth Defined Synchronous Scan Rate	0..15
127	Azimuth Offset Correction	0..15
128	Azimuth Stall Error Threshold	0..15
129	Azimuth Stall Count Threshold	0..9
	Spare Bits	10..15
130	Brake Command Status	0..3
	Brake Motion Status	4..7
	Brake Position Status	8..11
	Spare Bits	12..15
131	Brake Commanded Position	0..11
	Spare Bits	12..15
132	Brake Current Position	0..11
	Spare Bits	12..15
133	Brake Position SUBMUX Channel	0..7
	Spare Bits	8..15
134	Brake Step Count	0..15
135	Brake Defined Released Position	0..11
	Spare Bits	12..15
136	Brake Defined Applied Position	0..11
	Spare Bits	12..15
137	Brake Defined Cage Position	0..11
	Spare Bits	12..15
138	Brake Defined Released Margin	0..11
	Spare Bits	12..15

Table A-4. Digital Data Word Definitions (Continued)

Word	Parameter Name	Bits (MSB = 0)
139	Brake Defined Applied Margin	0..11
	Spare Bits	12..15
140	Brake Defined Cage Margin	0..11
	Spare Bits	12..15
141	Azimuth Position Error Value	0..15
142	Safehold Input A Status	0
	Safehold Input B Status	1
	Safehold Response A Status	2..3
	Safehold Response B Status	4..5
	Spare Bits	6..15
143	ICP Watchdog Boot Status	0
	ICP Watchdog Enable Status	1
	ICP PROM Power Status	2
	ICP Sample Clock Interrupt Occured	3..4
	DMA Communication Status	5..7
	Spare Bits	8..15
144	ICP Scan Period Counter	0..15
145	ICP Memory Dump Start Address Offset	0..15
146	ICP Memory Dump Start Address Segment	0..15
147	ICP Memory Dump End Address Offset	0..15
148	ICP Memory Dump End Address Segment	0..15
149	ICP Packet Start Address Offset	0..15
150	ICP Packet Start Address Segment	0..15
151	ICP Address Changed Indicator	0..15
152	ICP Minimum Execution Time	0..15
153	ICP Minimum Sample Number	0..10
	Spare Bits	11..15
154	ICP Maximum Execution Time	0..15
155	ICP Maximum Sample Number	0..10
	Spare Bits	11..15
156	ICP RAM Code Checksum	0..15
157	ICP ROM Code Checksum	0..15
158	Spare Word	0..15
159	Spare Word	0..15
160	Spare Word	0..15
161	Spare Word	0..15
162	Spare Word	0..15
163	SPS 1 State	0
	SPS 2 State	1
	SPS 1 Response	2
	SPS 2 Response	3
	Solar Warning	4..5
	Scan Timeout Response	6
	Scan Timeout Counting	7..8
	Scan Timeout Occurred	9..10
	Spare Bits	11..15
164	Solar Warning Event Sample Number	0..15
165	Solar Warning Event Scan Period	0..15
166	Scan Timeout Scan Period	0..15
167	SPS 1 Narrow FOV Signal	0..11
	Spare Bits	12..15

Table A-4. Digital Data Word Definitions (Continued)

Word	Parameter Name	Bits (MSB = 0)
168	SPS 1 Wide FOV Signal	0..11
	Spare Bits	12..15
169	SPS 1 Threshold Noise	0..11
	Spare Bits	12..15
170	SPS 1 Threshold Scale Numerator	0..5
	Spare Bits	6..15
171	SPS 1 Solar Detection State	0
	Spare Bits	1..15
172	SPS 1 Solar Detection Count	0..9
	Spare Bits	10..15
173	SPS 1 Solar Detection Count Threshold	0..9
	Spare Bits	10..15
174	SPS 1 Solar Detection Max Count	0..9
	Spare Bits	10..15
175	SPS 2 Narrow FOV Signal	0..11
	Spare Bits	12..15
176	SPS 2 Wide FOV Signal	0..11
	Spare Bits	12..15
177	SPS 2 Threshold Noise	0..11
	Spare Bits	12..15
178	SPS 2 Threshold Scale Numerator	0..5
	Spare Bits	6..15
179	SPS 2 Solar Detection State	0
	Spare Bits	1..15
180	SPS 2 Solar Detection Count	0..9
	Spare Bits	10..15
181	SPS 2 Solar Detection Count Threshold	0..9
	Spare Bits	10..15
182	SPS 2 Solar Detection Max Count	0..9
	Spare Bits	10..15
183	Solar Avoidance Initial Scan Count	0..9
	Spare Bits	10..15
184	Solar Avoidance Current Scan Count	0..9
	Spare Bits	10..15

Table A-5. BDS Quality Flag Definition

Bits (MSB = 0)	Flag Parameter	Definition
0..3	Azimuth Position Status	0000 = At GoTo Position 0001 = At Stopped 0010 = At Initial Position 0011 = At Scan Position 0100 = In Motion All Others = Undefined
4..7	Elevation Scan Mode	0000 = Normal Earth Scan 0001 = Short Earth Scan 0010 = MAM Scan Profile 0011 = NADIR Scan Profile 0100 = Stowed Profile All Others = Undefined

Table A-5. BDS Quality Flag Definition (Continued)

Bits (MSB = 0)	Flag Parameter	Definition
8..8	Shortwave Radiance	0 = Good, 1 = Bad
9..9	Window Radiance	0 = Good, 1 = Bad
10..10	Total Radiance	0 = Good, 1 = Bad
11..12	Spaceclamp Algorithm	00 = No Clamp 01 = Dual Scan Clamp 10 = Single Scan Clamp 11 = Undefined
13..14	Science Scan Mode	0 = Crosstrack, 1 = Biaxial
15..15	Spare	
16..19	Geolocation Flag	0000 = Good 0001 = Failed Instrument Checks 0010 = Failed Spacecraft Checks 0011 = Failed Algorithm Checks All Others = Undefined
20..31	Spares	

Table A-6. Temperature Counts Record

Field No.	Field Name / Parameter	Data Type	Units	Range	No. of Components
1	Total Channel Heater DAC Value	U16 Integer	N/A	N/A	12
2	SW Channel Heater DAC Value	U16 Integer	N/A	N/A	12
3	LW Channel Heater DAC Value	U16 Integer	N/A	N/A	12
4	Blackbody Heater DAC Value	U16 Integer	N/A	N/A	12
5	Total Detector Control Temperature	U16 Integer	counts	0..4095	12
6	Total Detector Monitor Temperature	U16 Integer	counts	0..4095	12
7	SW Detector Control Temperature	U16 Integer	counts	0..4095	12
8	SW Detector Monitor Temperature	U16 Integer	counts	0..4095	12
9	LW Detector Control Temperature	U16 Integer	counts	0..4095	12
10	LW Detector Monitor Temperature	U16 Integer	counts	0..4095	12
11	Total Blackbody Temperature	U16 Integer	counts	0..4095	12
12	LW Blackbody Temperature	U16 Integer	counts	0..4095	12
13	Elevation Spindle Temperature (Motor)	U16 Integer	counts	0..4095	3
14	Elevation Spindle Temperature (Cable Wrap)	U16 Integer	counts	0..4095	3
15	Elevation Bearing Temperature (Motor)	U16 Integer	counts	0..4095	3
16	Elevation Bearing Temperature (Cable Wrap)	U16 Integer	counts	0..4095	3
17	SWICS Photodiode Temperature	U16 Integer	counts	0..4095	3
18	Sensor Module Temperature	U16 Integer	counts	0..4095	3
19	Sensor Electronics Temperature	U16 Integer	counts	0..4095	3
20	Main Cover Motor Temperature	U16 Integer	counts	0..4095	3
21	MAM Total Baffle Temperature 1	U16 Integer	counts	0..4095	3
22	MAM Total Baffle Temperature 2	U16 Integer	counts	0..4095	3
23	MAM Assembly SW Temperature	U16 Integer	counts	0..4095	3
24	MAM Assembly Total Temperature	U16 Integer	counts	0..4095	3

Table A-6. Temperature Counts Record (Continued)

Field No.	Field Name / Parameter	Data Type	Units	Range	No. of Components
25	DAA Radiator Temperature	U16 Integer	counts	0..4095	3
26	DAA Processor Electronics Temperature	U16 Integer	counts	0..4095	3
27	DAA ADC Electronics Temperature	U16 Integer	counts	0..4095	3
28	ECA Radiator Temperature	U16 Integer	counts	0..4095	3
29	ECA Electronics Temperature	U16 Integer	counts	0..4095	3
30	ACA Electronics Temperature	U16 Integer	counts	0..4095	3
31	Azimuth Lower Bearing Temperature	U16 Integer	counts	0..4095	3
32	Azimuth Upper Bearing Temperature	U16 Integer	counts	0..4095	3
33	ICA Radiator Temperature	U16 Integer	counts	0..4095	3
34	ICA Processor Electronics Temperature	U16 Integer	counts	0..4095	3
35	ICA ADC Electronics Temperature	U16 Integer	counts	0..4095	3
36	PCA Radiator Temperature	U16 Integer	counts	0..4095	3
37	PCA Electronics Temperature	U16 Integer	counts	0..4095	3
38	Pedestal Temperature 1 (Brake Housing)	U16 Integer	counts	0..4095	3
39	Pedestal Temperature 2 (Isolator)	U16 Integer	counts	0..4095	3

Table A-7. Voltage and Torque Counts Record

Field No.	Field Name / Parameter	Data Type	Units	Range	No. of Components
1	Detector +120V Bias	U16 Integer	counts	0..4095	3
2	Detector -120V Bias	U16 Integer	counts	0..4095	3
3	SWICS Photodiode Output	U16 Integer	counts	0..4095	3
4	SWICS Lamp Current	U16 Integer	counts	0..4095	3
5	ICA +5V Digital	U16 Integer	counts	0..4095	3
6	ICA +15V to ECA/ACA	U16 Integer	counts	0..4095	3
7	ICA -15V to ECA/ACA	U16 Integer	counts	0..4095	3
8	ICA + 5V Analog	U16 Integer	counts	0..4095	3
9	ICA +10V Bias	U16 Integer	counts	0..4095	3
10	ICA +15V Internal	U16 Integer	counts	0..4095	3
11	ICA -15V Internal	U16 Integer	counts	0..4095	3
12	DAA Ground Reference 1	U16 Integer	counts	0..4095	3
13	DAA Ground Reference 2	U16 Integer	counts	0..4095	3
14	DAA -10V Reference	U16 Integer	counts	0..4095	3
15	DAA +130V	U16 Integer	counts	0..4095	3
16	DAA -130V	U16 Integer	counts	0..4095	3
17	DAA +12V	U16 Integer	counts	0..4095	3
18	DAA -12V	U16 Integer	counts	0..4095	3
19	DAA +15V	U16 Integer	counts	0..4095	3
20	DAA -15V	U16 Integer	counts	0..4095	3
21	DAA +5V	U16 Integer	counts	0..4095	3
22	DAA +10V Reference	U16 Integer	counts	0..4095	3
23	ECA Torque Output	U16 Integer	counts	0..4095	12
24	ACA Torque Output	U16 Integer	counts	0..4095	12

Table A-8. Position Counts Record

Field No.	Field Name / Parameter	Data Type	Units	Range	No. of Components
1	ACA Encoder Clear Track A	U16 Integer	counts	0..4095	3
2	ACA Encoder Clear Track B	U16 Integer	counts	0..4095	3
3	ECA Encoder Clear Track A	U16 Integer	counts	0..4095	3
4	ECA Encoder Clear Track B	U16 Integer	counts	0..4095	3
5	Main Cover Position 1	U16 Integer	counts	0..4095	3
6	Main Cover Position 2	U16 Integer	counts	0..4095	3
7	MAM Cover Position	U16 Integer	counts	0..4095	3
8	Azimuth Brake Position	U16 Integer	counts	0..4095	3
9	SPS 1 Narrow FOV	U16 Integer	counts	0..4095	60
10	SPS 1 Wide FOV	U16 Integer	counts	0..4095	60
11	SPS 2 Narrow FOV	U16 Integer	counts	0..4095	60
12	SPS 2 Wide FOV	U16 Integer	counts	0..4095	60

Table A-9. Converted Temperatures Record

Field No.	Field Name / Parameter	Data Type	Units	Range	No. of Components
1	Total Detector Control Temperature	32 Bit Float	^oC	36.0..40.0	12
2	Total Detector Monitor Temperature	32 Bit Float	^oC	36.0..40.0	12
3	SW Detector Control Temperature	32 Bit Float	^oC	36.0..40.0	12
4	SW Detector Monitor Temperature	32 Bit Float	^oC	36.0..40.0	12
5	LW Detector Control Temperature	32 Bit Float	^oC	36.0..40.0	12
6	LW Detector Monitor Temperature	32 Bit Float	^oC	36.0..40.0	12
7	Total Blackbody Temperature	32 Bit Float	^oC	-15.0..60.0	12
8	LW Blackbody Temperature	32 Bit Float	^oC	-15.0..60.0	12
9	Elevation Spindle Temperature (Motor)	32 Bit Float	^oC	-30.0..70.0	3
10	Elevation Spindle Temperature (Cable Wrap)	32 Bit Float	^oC	-30.0..70.0	3
11	Elevation Bearing Temperature (Motor)	32 Bit Float	^oC	-30.0..70.0	3
12	Elevation Bearing Temperature (Cable Wrap)	32 Bit Float	^oC	-30.0..70.0	3
13	SWICS Photodiode Temperature	32 Bit Float	^oC	-30.0..70.0	3
14	Sensor Module Temperature	32 Bit Float	^oC	-30.0..70.0	3
15	Sensor Electronics Temperature	32 Bit Float	^oC	-30.0..70.0	3
16	Main Cover Motor Temperature	32 Bit Float	^oC	-30.0..70.0	3
17	MAM Total Baffle Temperature 1	32 Bit Float	^oC	-30.0..70.0	3
18	MAM Total Baffle Temperature 2	32 Bit Float	^oC	-30.0..70.0	3
19	MAM Assembly SW Temperature	32 Bit Float	^oC	-30.0..70.0	3
20	MAM Assembly Total Temperature	32 Bit Float	^oC	-30.0..70.0	3
21	DAA Radiator Temperature	32 Bit Float	^oC	-30.0..70.0	3
22	DAA Processor Electronics Temperature	32 Bit Float	^oC	-30.0..70.0	3
23	DAA ADC Electronics Temperature	32 Bit Float	^oC	-30.0..70.0	3
24	ECA Radiator Temperature	32 Bit Float	^oC	-30.0..70.0	3
25	ECA Electronics Temperature	32 Bit Float	^oC	-30.0..70.0	3
26	ACA Electronics Temperature	32 Bit Float	^oC	-30.0..70.0	3
27	Azimuth Lower Bearing Temperature	32 Bit Float	^oC	-30.0..70.0	3
28	Azimuth Upper Bearing Temperature	32 Bit Float	^oC	-30.0..70.0	3
29	ICA Radiator Temperature	32 Bit Float	^oC	-30.0..70.0	3

Table A-9. Converted Temperatures Record

Field No.	Field Name / Parameter	Data Type	Units	Range	No. of Components
30	ICA Processor Electronics Temperature	32 Bit Float	^oC	-30.0..70.0	3
31	ICA ADC Electronics Temperature	32 Bit Float	^oC	-30.0..70.0	3
32	PCA Radiator Temperature	32 Bit Float	^oC	-30.0..70.0	3
33	PCA Electronics Temperature	32 Bit Float	^oC	-30.0..70.0	3
34	Pedestal Temperature 1 (Brake Housing)	32 Bit Float	^oC	-30.0..70.0	3
35	Pedestal Temperature 2 (Isolator)	32 Bit Float	^oC	-30.0..70.0	3

Vdata Name: Voltages and Torques
Number of Records: n

Number of Fields: 23
Parameter(s): Table B-8

Table A-10. Converted Voltages and Torques Record

Field No.	Field Name / Parameter	Data Type	Units	Range	No. of Components
1	Sensor +120V Bias	32 Bit Float	volts	115.0..125.0	3
2	Sensor -120V Bias	32 Bit Float	volts	-125.0..-115.0	3
3	SWICS Lamp Current	32 Bit Float	mA	0.0..100.0	3
4	ICA +5V Digital	32 Bit Float	volts	0.0..8.0	3
5	ICA +15V to ECA/ICA	32 Bit Float	volts	0.0..20.0	3
6	ICA -15V to ECA/ICA	32 Bit Float	volts	-20.0..0.0	3
7	ICA +5V Analog	32 Bit Float	volts	0.0..20.0	3
8	ICA +10V Bias	32 Bit Float	volts	-20.0..0.0	3
9	ICA +15V Internal	32 Bit Float	volts	0.0..30.0	3
10	ICA -15V Internal	32 Bit Float	volts	-30.0..0.0	3
11	DAA Ground Reference 1	32 Bit Float	volts	0.0..10.0	3
12	DAA Ground Reference 2	32 Bit Float	volts	0.0..10.0	3
13	DAA -10V Reference	32 Bit Float	volts	-20.0..0.0	3
14	DAA +130V	32 Bit Float	volts	90.0..170.0	3
15	DAA -130V	32 Bit Float	volts	-224.0..-36.0	3
16	DAA +12V	32 Bit Float	volts	0.0..20.0	3
17	DAA -12V	32 Bit Float	volts	-20.0..0.0	3
18	DAA +15V	32 Bit Float	volts	0.0..20.0	3
19	DAA -15V	32 Bit Float	volts	-20.0..0.0	3
20	DAA +5V	32 Bit Float	volts	0.0..20.0	3
21	DAA +10V Reference	32 Bit Float	volts	-20.0..0.0	3
22	Elevation Torque Output	32 Bit Float	in-oz	-95.7..95.2	12
23	Azimuth Torque	32 Bit Float	in-oz	-266.7..265.2	12

Table A-11. Satellite Positions Record

Field No.	Field Names / Parameters	Data Type	Units	Range	No. of Components
1	Satellite Position X at record start	64 Bit Float	km	-8000..8000	1
2	Satellite Position Y at record start	64 Bit Float	km	-8000..8000	1
3	Satellite Position Z at record start	64 Bit Float	km	-8000..8000	1
4	Satellite Position X at record end	64 Bit Float	km	-8000..8000	1
5	Satellite Position Y at record end	64 Bit Float	km	-8000..8000	1
6	Satellite Position Z at record end	64 Bit Float	km	-8000..8000	1
7	Satellite Velocity X at record start	64 Bit Float	km sec^{-1}	-10.0..10.0	1
8	Satellite Velocity Y at record start	64 Bit Float	km sec^{-1}	-10.0..10.0	1
9	Satellite Velocity Z at record start	64 Bit Float	km sec^{-1}	-10.0..10.0	1
10	Satellite Velocity X at record end	64 Bit Float	km sec^{-1}	-10.0..10.0	1
11	Satellite Velocity Y at record end	64 Bit Float	km sec^{-1}	-10.0..10.0	1
12	Satellite Velocity Z at record end	64 Bit Float	km sec^{-1}	-10.0..10.0	1
13	Colatitude of satellite at record start	64 Bit Float	degrees	0.0..180.0	1
14	Longitude of satellite at record start	64 Bit Float	degrees	0.0..360.0	1
15	Colatitude of satellite at record end	64 Bit Float	degrees	0.0..180.0	1
16	Longitude of satellite at record end	64 Bit Float	degrees	0.0..360.0	1
17	Earth-Sun Distance	64 Bit Float	AU	0.98..1.02	1
18	Number of Orbits	U32 Integer	N/A	TBD	1
19	Colatitude of Sun at observation	64 Bit Float	degrees	0.0..180.0	1
20	Longitude of Sun ar observation	64 Bit Float	degrees	0.0..360.0	1

Table A-12. Converted Digital Data

Field No.	Field Names / Parameters	Data Type	Units	Range	No. of Components
1	Elevation Offset Correction	32 Bit Float	degrees		1
2	Azimuth Offset Correction	32 Bit Float	degrees		1
3	Azimuth Defined Crosstrack Position	32 Bit Float	degrees		1
4	Azimuth Defined Fixed Position A	32 Bit Float	degrees		1
5	Azimuth Defined Fixed Position B	32 Bit Float	degrees		1
6	Azimuth Defined Fixed Solar Cal Position	32 Bit Float	degrees		1
7	Azimuth Defined Fixed Cage Position	32 Bit Float	degrees		1
8	Azimuth Defined Fixed Position Spare 1	32 Bit Float	degrees		1
9	Azimuth Defined Fixed Position Spare 2	32 Bit Float	degrees		1
10	Azimuth Defined Fixed Position Spare 3	32 Bit Float	degrees		1
11	Azimuth Defined Normal Slew Rate	32 Bit Float	deg sec^{-1}		1
12	Azimuth Defined Asynchronous Scan Rate	32 Bit Float	deg sec^{-1}		1
13	Azimuth Defined Synchronous Scan Rate	32 Bit Float	deg sec^{-1}		1
14	DAP Minimum Execution Time	32 Bit Float	sec		1
15	DAP Maximum Execution Time	32 Bit Float	sec		1
16	ICP Minimum Execution Time	32 Bit Float	sec		1
17	ICP Maximum Execution Time	32 Bit Float	sec		1
18	Instrument ID Number	U8 Integer	N/A		1
19	Packet Data Indicator	U8 Integer	N/A		1
20	Packet Data Version	U8 Integer	N/A		1
21	Science Packet Quick Look Flag Status	U8 Integer	N/A		1
22	Packet Timecode Indicator	U8 Integer	N/A		1
23	Packet Counter	U16 Integer	N/A		1

Appendix B

Output Data Products

ERBE-like Inversion to Instantaneous TOA Fluxes (Subsystem 2.0)

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		Name	Type	Frequency	Size, MB	Monthly size, MB
CERES	EOSDIS					
ES-8	CER02	ERBE-like Instantaneous TOA Estimates	archival	1/day	322.4	9994
EDDB/EID-6	None	ERBE-like daily database	internal	1/day	6.5	202

ERBE-like Instantaneous TOA Estimates (ES-8)

EOSDIS Product Code: CER02

The ES-8 data product contains a 24-hour, single-satellite, instantaneous view of scanner fluxes at the top-of-atmosphere reduced from spacecraft altitude unfiltered radiances using the ERBE scanner Inversion algorithms and the ERBE shortwave (SW) and longwave (LW) ADMs. The ES-8 also includes the SW, LW, and window (WN) channel radiometric data; SW, LW, and WN unfiltered radiance values; and the ERBE scene identification results on a pixel basis. These data are organized according to the CERES 3.3-sec scan into 6.6-sec records. These records contain only Earth-viewing measurements, approximately 450 for TRMM and 390 for EOS. As long as there is one valid scanner measurement within a record, the ES-8 record will be generated.

The ES-8 is output by the CERES ERBE-like process. The top-of-the-atmosphere (TOA) fluxes for each CERES pixel are archived on the ES-8, as well as flags describing instrument status, the radiometric data, and FOV location. A complete listing of parameters for this data product can be found in Table 2-5.

Specifically, the ES-8 contains the following kinds of information:

1. Scan-Level Data
   a) Julian date and time
   b) Earth-Sun distance
   c) Satellite position and velocity and Sun position
   d) Orbit number

2. Pixel-Level Data
   a) Satellite instrument FOV data
   b) Radiometric data
   c) Satellite and Sun geometry data
   d) Unfiltered radiances
   e) TOA fluxes
   f) ERBE scene identification

(1) clear ocean	(5) clear coastal	(9) mostly cloudy ocean
(2) clear land	(6) partly cloudy ocean	(10) mostly cloudy land-desert
(3) clear snow	(7) partly cloudy land-desert	(11) mostly cloudy coastal
(4) clear desert	(8) partly cloudy coastal	(12) overcast

The ES-8 will be produced starting at launch and will be externally archived for use by the global scientific community.

Level: 2
Type: Archival
Frequency: 1/Day

Time Interval Covered
- **File:** 24 hours
- **Record:** 6.6 seconds

Portion of Globe Covered
- **File:** Satellite swath
- **Record:** N/A

Portion of Atmosphere Covered
- **File:** Satellite altitude and TOA

Table B-2: ERBE-like Instantaneous TOA Estimates (ES-8)

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Elem Num
ES-8						
ES-8_File_Header						
ES-8 File header		N/A		TBD	TBD	
ES-8_Data_Record						
Scan_Level_Data						
Julian day	1	day	2449353 .. 2458500	1	32	1
Julian time	2	10^{-9} day	0 .. 999999999	1	32	2
Earth-Sun distance	3	10^{-9} AU	$98*10^6$ ..$102*10^6$	1	32	3
X component of satellite position	4	km	-8000 .. 8000	2	32	4
Y component of satellite position	5	km	-8000 .. 8000	2	32	6
Z component of satellite position	6	km	-8000 .. 8000	2	32	8
X component of satellite inertial velocity	7	km/sec	-10 .. 10	2	32	10
Y component of satellite inertial velocity	8	km/sec	-10 .. 10	2	32	12
Z component of satellite inertial velocity	9	km/sec	-10 .. 10	2	32	14
Colatitude of satellite at observation	10	deg	0 .. 180	2	32	16
Longitude of satellite at observation	11	deg	0 .. 360	2	32	18
Colatitude of Sun at observation	12	deg	0 .. 180	1	32	20
Longitude of Sun at observation	13	deg	0 .. 360	1	32	21
Satellite orbit number	14	N/A	0 .. 54000	1	32	22
Pixel_Level_Flag_Words						
Scanner operations flag word	15	N/A	N/A	2	32	23
Quality flag for total radiance value	16	N/A	N/A	33	32	25
Quality flag for shortwave radiance value	17	N/A	N/A	33	32	58
Quality flag for window radiance value	18	N/A	N/A	33	32	91
Quality flag for FOV	19	N/A	N/A	33	32	124
Pixel_Level_Data						
Colatitude of FOV at TOA	20	deg	0 .. 180	450	32	157
Longitude of FOV at TOA	21	deg	0 .. 360	450	32	607
Total filtered radiance, upwards	22	W $m^{-2}sr^{-1}$	0 .. 700	450	32	1057
Shortwave filtered radiance, upwards	23	W $m^{-2}sr^{-1}$	-10 .. 510	450	32	1507
Window filtered radiance, upwards	24	W $m^{-2}sr^{-1}$	0 .. 50	450	32	1957
Viewing zenith at TOA	25	deg	0 .. 90	450	32	2407
Solar zenith at TOA	26	deg	0 .. 180	450	32	2857
Relative azimuth at TOA	27	deg	0 .. 360	450	32	3307
Shortwave unfiltered radiance, upwards	28	W m^{-2}	-10 .. 510	450	32	3757
Longwave unfiltered radiance, upwards	29	W m^{-2}	0 .. 200	450	32	4207
Window unfiltered radiance, upwards	30	W m^{-2}	0 .. 50	450	32	4657
Shortwave flux at TOA, upwards	31	W m^{-2}	0 .. 1400	450	32	5107
Longwave flux at TOA, upwards	32	W m^{-2}	50 .. 400	450	32	5557
ERBE scene type	33	N/A	0 .. 12.4	450	32	6007

Total Meta Bits/File:	TBD
Total Data Bits/Record:	206592
Total Records/File:	13091
Total Data Bits/File:	2704495872
Total Bits/File:	2704495872

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 of several parameters on the ERBE 2.5-deg 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	**Portion of Globe Covered**
Type: Internal	**File:** Regional
Frequency: 1/Day	**Record:** Individual Region
Time Interval Covered	**Portion of Atmosphere Covered**
File: Day	**File:** TOA
Record: N/A	

Table B-3: 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 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
$\dot{N}$	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
$H_2O\lambda(p$	spectral optical depth profiles of water vapor
$O_3(p$	spectral optical depth profiles of ozone
Φ	longitude of satellite
ϕ	azimuth angle
ω_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