Earth Radiation Budget Experiment Regional, Zonal, and Global Gridded Averages Output Product (S-4G) Langley ASDC Data Set Document

Summary:

This document describes the Regional, Zonal, and Global Gridded Averages (S-4G) Output Product and provides the user with the necessary information to use the Earth Radiation Budget Experiment data for scientific research studies.

The S-4G product is produced by the ERBE Data Management Team and is archived at the EOSDIS Langley ASDC. It contains the same time and space averages of all the individual estimates of radiant flux at the top-of-the-atmosphere for one month and one spacecraft or combination of spacecraft as the S-4 product. The difference between the two products is that S-4 is arranged by region, with all parameters for a region grouped together, while S-4G presents gridded data, with all regions for a given parameter grouped together.

The S-4G data set consists of scanner and nonscanner data processed for the months in which the scanners were operative. During this processing, the nonscanner data were processed using scene identification information (see Table 14) from the scanners.

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1. Data Set Overview:

Data Set Identification:

Data are archived as the Regional, Zonal, and Global Gridded, Averages Product (S-4G). There are 14 data sets that make up a S-4G data product. The data sets are as follows:

- **ERBE_S4G_SC_2.5**: Earth Radiation Budget Experiment (ERBE) S-4G Scanner (SC) 2.5 degree Regional Averages in Hierarchical Data Format (ERBE_S4G_SC_2.5)
- **ERBE_S4G_SC_NEST10**: Earth Radiation Budget Experiment (ERBE) S-4G Scanner (SC) 5 degree nested to 10 degree Regional Averages in Hierarchical Data Format (ERBE_S4G_SC_NEST10)
- **ERBE_S4G_SC_NEST5**: Earth Radiation Budget Experiment (ERBE) S-4G Scanner (SC) 2.5 degree nested to 5 degree Regional

Averages in Hierarchical Data Format (ERBE_S4G_SC_NEST5)
- **ERBE_S4G_SC_ZG**: Earth Radiation Budget Experiment (ERBE) S-4G Scanner (SC) 2.5, 5, 10 degrees Zonal and Global Regional Averages in Hierarchical Data Format (ERBE_S4G_SC_ZG)
- **ERBE_S4G_MFOV_NF**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Medium Field of View (MFOV) Numerical Filter (NF) 5 degree Regional Averages in Hierarchical Data Format (ERBE_S4G_MFOV_NF)
- **ERBE_S4G_MFOV_NF_N10**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Medium Field of View (MFOV) Numerical Filter (NF) 5 degree nested to 10 degree Regional Averages in Hierarchical Data Format (ERBE_S4G_MFOV_NF_N10)
- **ERBE_S4G_MFOV_NF_ZG**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Medium Field of View (MFOV) Numerical Filter (NF) Zonal and Global Averages in Hierarchical Data Format (ERBE_S4G_MFOV_NF_ZG)
- **ERBE_S4G_MFOV_SF**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Medium Field of View (MFOV) Shape Factor (SF) 10 degree Regional Averages in Hierarchical Data Format (ERBE_S4G_MFOV_SF)
- **ERBE_S4G_MFOV_SF_ZG**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Medium Field of View (MFOV) Shape Factor (SF) Zonal and Global Averages in Hierarchical Data Format (ERBE_S4G_MFOV_SF_ZG)
- **ERBE_S4G_WFOV_NF**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Wide Field of View (WFOV) Numerical Filter (NF) 5 degree Regional Averages in Hierarchical Data Format (ERBE_S4G_WFOV_NF)
- **ERBE_S4G_WFOV_NF_N10**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Wide Field of View (WFOV) Numerical Filter (NF) 5 degree nested to 10.0 degree Regional Averages in Hierarchical Data Format (ERBE_S4G_WFOV_NF_N10)
- **ERBE_S4G_WFOV_NF_ZG**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Wide Field of View (WFOV) Numerical Filter (NF) 5.0 and 10.0 degree Zonal and Global Averages in Hierarchical Data Format (ERBE_S4G_WFOV_NF_ZG)
- **ERBE_S4G_WFOV_SF**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Wide Field of View (WFOV) Shape Factor (SF) 10 degree Regional Averages in Hierarchical Data Format (ERBE_S4G_WFOV_SF)
- **ERBE_S4G_WFOV_SF_ZG**: Earth Radiation Budget Experiment (ERBE) S-4G Nonscanner, Wide Field of View (WFOV) Shape Factor (SF) 10 degree Zonal and Global Averages in Hierarchical Data Format (ERBE_S4G_WFOV_SF_ZG)

Data Set Introduction:

The S-4G contains averages of flux and albedo on regional, zonal, and global scales for both scanner and nonscanner.

Objective/Purpose:

The objectives of ERBE are:

1. To determine, for a minimum of 1 year, the monthly average radiation budget on regional, zonal, and global scales.
2. To determine the equator-to-pole energy transport gradient.
3. To determine the average diurnal variation of the radiation budget on a regional and monthly scale.

Summary of Parameters:

The S-4G product contains the same averages of flux and albedo on regional, zonal, and global scales for both scanner and nonscanner data as the S-4 product. The difference in these products is the arrangement of the data; the S-4G product is arranged by parameter values while the S-4 product is arranged by region. The S-4G is available as a combination of all operational spacecraft (ERBS, NOAA-9, and NOAA-10) for the scanner data and the wide field-of-view (WVOF) data. It is available as a combination of the ERBS and NOAA-9 spacecraft for medium field-of-view (MFOV). Single satellite data will soon be available. The S-4G consists of 14 Hierarchical Data Format (HDF) files per month. Each file contains a variable number of HDF Scientific Data Set Structures, depending on data type and resolution. Monthly (day), monthly (hour), daily, and monthly hourly averages are determined for each region. The data are represented as 8-, 16-, and 32-bit integers. The values contained are as follows:

- Geographic scene type
- Monthly mean shortwave flux
- Monthly mean longwave flux
- Monthly mean albedo
- Monthly mean net flux
- Monthly total integrated solar incidence
- Monthly mean clear-sky shortwave flux
- Monthly mean clear-sky longwave flux
- Monthly mean clear-sky albedo
- Monthly mean clear-sky net flux
- Statistics such as the number of days that contain shortwave/ longwave measurements for a given hour

Discussion:

The goal of the ERBE is to produce monthly averages of longwave and shortwave radiation parameters on the Earth at regional to global scales. Preflight mission analysis lead to a three-spacecraft system to provide the geographic and temporal sampling required to meet this goal. Three nearly identical sets of instruments were built and launched on three separate spacecraft. These instruments differ principally in the spacecraft interface electronics and in the field-of-view limiters for the nonscanner instruments required because of differences in the spacecraft orbit altitudes.

The ERBS spacecraft was launched by Space Shuttle Challenger in October 1984 and was the first spacecraft to carry ERBE instruments into orbit. The ERBS was designed and built by Ball Aerospace Systems under contract to NASA Goddard Space Flight Center (GSFC), and ERBS was the first spacecraft dedicated to NASA science experiments to be launched by the Space Shuttle. The ERBS carries the Stratospheric Aerosol and Gas Experiment (SAGE II) instrument in addition to the ERBE instruments. The Payload Operation and Control Center (POCC) at GSFC directs operations of the ERBS spacecraft and the ERBE and SAGE II instruments, employing both ground stations and the Tracking and Data Relay Satellite System (TDRSS) network. Spacecraft and instrument telemetry data are received at GSFC where the data are processed by the Information Processing Division that provides ERBE and SAGE II experiment data to the NASA Langley Research Center (LaRC).

The second and third spacecraft launched with ERBE instruments are Television Infrared Radiometer Orbiting Satellite (TIROS) N-class spacecraft, which are part of the NOAA operational meteorological satellite series. The NOAA-9 and NOAA-10 spacecraft were launched in December 1984 and September 1986, respectively. The NOAA spacecraft include other instruments, such as the Advanced Very High Resolution Radiometer (AVHRR) and the High-Resolution Infrared Radiometer Sounder (HIRS), which provide NOAA with data for near-real-time weather forecasting. Both spacecraft are in nearly sun-synchronous orbits. The equator-crossing times (at launch) of the orbital nodes for the NOAA-9 and NOAA-10 orbits were 1420 UT (ascending) and 1930 UT (descending), respectively, where UT denotes universal time. The Satellite Operations and Control Center (SOCC) at the National Environmental Satellite and Data Information Service (NESDIS) operates the NOAA spacecraft. NOAA also provides decommutation processing of the telemetry data.

NASA tracks the ERBS spacecraft, and the North American Aerospace Defense Command (NORAD) tracks the NOAA spacecraft. The tracking data are provided to GSFC where orbit ephemeris data are calculated for all three spacecraft and provided to LaRC.

Related Data Sets:

SRB_Daily:	Surface Radiation Budget Daily Averages
SRB_Monthly:	Surface Radiation Budget Monthly Averages

2. Investigator(s):

Investigator(s) Name and Title:

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Title of Investigation:

Earth Radiation Budget Experiment (ERBE)

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3. Theory of Measurements:

The theory behind the measurements made to collect the ERBE data is non-trivial and well beyond the scope of this document. However, interested readers are referred to the following publications: NASA Reference Publication 1184, *Angular radiation models for Earth-atmosphere system, Volume 1: Shortwave radiation*, and *Volume 2: Longwave radiation*; NASA Technical Paper 2670, *Calculation and accuracy of ERBE scanner measurement locations*; and Smith (Reference 13).

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

All three sets of ERBE instruments were designed to collect data for one year but had a goal of two years. The nonscanner instruments continue to collect data for ERBS; however, the nonscanner instruments on-board NOAA-9 and NOAA-10 have been deactivated. Table 1 describes the nominal orbit parameters for each satellite at launch.

Table 1. Nominal Orbit Parameters for Each Satellite at Launch

Nominal Orbit Parameter	ERBS	NOAA-9	NOAA-10
Launch Date	October 5, 1984	December 12, 1984	September 17, 1986
Planned Duration	1 Year	1 Year	1 Year
Actual Duration Scanner	5-1/2 years (February 28, 1990)	3 years (January 20, 1987)	2-1/2 years (May 22, 1989)
Actual Duration Nonscanner	Operating	Over 12 years, deactivated April 3, 1997	Over 8 years, deactivated December, 1994
Orbit	Precessing	Sun-synchronous	Sun-synchronous
Semi-major Axis	6988 km	7248 km	7211 km
Mean Altitude	610 km	872 km	833 km
Inclination	57 deg	98 deg	98 deg
Nodal Period	98 minutes	102.08 minutes	101.2 minutes
Equator Crossing Time (at launch)	Variable	1430 Local Mean Solar Time, ascending	0730 Local Mean Solar Time, descending

Source/Platform:

The ERBE instruments are on the ERBS, NOAA-9, and NOAA-10 satellites.

Source/Platform Mission Objectives:

ERBS was the first spacecraft dedicated to NASA science experiments to be launched by the Space Shuttle. ERBS carries SAGE IIinstruments in addition to the ERBE instruments. The NOAA spacecraft include other instruments, such as the Advanced Very High Resolution Radiometer (AVHRR) and the High-Resolution Infrared Radiometer Sounder (HIRS), which provide NOAA with data for near-real-time weather forecasting.

Key Variables:

A complete list of the measured parameters is found in Table 2.

Table 2. ERBS, NOAA-9, and NOAA-10 ERBE Detector Characteristics

	CHANNEL	WAVELENGTH LIMITS (microns)	MEASUREMENT
Nonscanner Fixed Wide field of view	1	0.2-50.0	Total Radiance
	2	0.2 - 5.0	Shortwave Reflected
Nonscanner Fixed Medium field-of-view	3	0.2 - 50.0	Total Radiance
	4	0.2 - 5.0	Shortwave Reflected
Fixed Solar Monitor	5	0.2 - 50.0	Total Irradiance
Scanner Narrow field-of-view	1	0.2 - 50.0	Total Radiance
	2	0.2 - 45.0	Shortwave Reflected
	3	5.0 - 50.0	Longwave Emitted

Principles of Operation:

The ERBE is a multisatellite system designed to measure the Earth's radiation budget. The ERBE instruments fly on a mid-inclination NASA satellite, (ERBS), and two sun-synchronous NOAA satellites, (NOAA-9 and NOAA-10). Each satellite carries both a scanner and a nonscanner instrument package with characteristics listed in Table 2.

The scanner package contains three radiometric detectors each of which consists of an f/1.84 Cassegrain telescope. All are located within a single, rotating scan-head which, when operating in the cross track azimuth position, scans the Earth perpendicular to the satellite ground track from horizon to horizon. The scan-head can also be rotated in azimuth at a slow rate (0.9 degrees/second NOAA, 0.675 degrees/second ERBS). Each detector samples 74 measurements per scan. The total detector has no filter and so absorbs all wavelengths. The shortwave detector has a Suprasil-W1 filter which transmits only shortwave radiation. The longwave detector has a multilayer filter on a diamond substrate to reject shortwave and accept longwave radiation. To enhance the spectral flatness of the detectors, each thermistor chip is coated with a thin layer of black paint.

The nonscanner instrument package contains four Earth-viewing channels and a solar monitor. The Earth-viewing channels have two spatial resolutions: a horizon-to-horizon view of the Earth, and a field-of-view limited to about 1000 km in diameter. The former are called the wide field-of-view (WFOV) and the latter the medium field-of-view (MFOV) channels. For each of the two fields of view, there is a total spectral channel which is sensitive to all wavelengths and a shortwave channel which uses a high purity, fused silica filter dome to transmit only the shortwave radiation from 0.2 to 5 microns. The solar monitor is a direct descendant of the Solar Maximum Mission's Active Cavity Radiometer Irradiance Monitor detector. Because of the concern for spectral flatness and high accuracy, all five of the channels on the nonscanner package are active cavity radiometers.

Sensor/Instrument Measurement Geometry:

The nonscanner elevation beams can be rotated to any of three positions: launch/stow/internal calibration position (180 degrees), solar calibration position (78 degrees), and Earth-viewing (nadir) position (0 degrees). The WFOV detectors view the Earth from limb-to-limb (plus a small ring of space). The MFOV detectors are designed to include approximately an Earth view of 10 geocentric degrees within the unencumbered field of view (FOV).

The scanner can rotate in azimuth between 0 degrees and 180 degrees with an accuracy of 0.075 degrees. The normal scan mode is cross-track. The effective FOV of the scanner is 3 degrees.

Manufacturer of Sensor/Instrument:

The ERBE instruments were developed by TRW, Inc.

Calibration:

Specifications:

Not applicable.

Tolerance:

The tolerance is 1 percent for the total channel and 2 percent for the shortwave channel.

Frequency of Calibration:

For the scanner instruments, in-flight calibrations were accomplished every scan, as well as on a bi-weekly basis. In-flight calibrations of the nonscanners were normally performed on a bi-weekly basis.

Other Calibration Information:

The ERBE instruments were developed by TRW, Inc. Laboratory calibrations of the ERBE nonscanner and solar monitor instruments were completed in the TRW calibration facility at Redondo Beach, California in 1984. The fundamental standards used for the ERBE instruments were the International Pressure and Temperature Standard of 1968 (IPTS-68) and the World Radiation Reference (WRR). The TRW master reference blackbody (MRBB) was calibrated using these, and the MRBB was subsequently used to transfer the calibrations to the internal blackbody (IBB) and to the shortwave channels via an integrating sphere. The results of the calibrations were reported in detail in TRW calibration documents.

In-flight calibrations are performed in order to maintain the accuracy of radiometric measurements by accounting for internal instrument component parametric changes brought about by the spacecraft's environmental variables. In-flight calibrations of the nonscanners were normally performed on a bi-weekly basis. These included internal calibrations, space looks, and solar calibrations. Internal calibrations consist of cycling of IBB temperatures (total sensors) and shortwave internal calibration source (SWICS) voltages. Space looks consist of observations of "cold" space, both before and after solar calibrations. Solar calibrations consist of measurements made while the solar disc is within the instrument's FOV.

On days when internal calibrations are performed, shortwave offsets are independently determined in four ways:

1. The preferred offsets are determined by using the aggregate of all earth-viewing data taken when the solar zenith angle is greater than 123 degrees, and assuming that the shortwave radiance is zero. Because of the solar zenith angle requirement, it is not always possible to use this method.
2. The second choice offsets are determined by using the data acquired during the internal calibration period, with the SWICS-off. Again it is presumed that the shortwave radiance is zero.
3. The third choice offsets are determined using data acquired during the so-called "B-soak" period which occurs before every internal calibration sequence is begun. During this period, all of the sensors are exposed to their respective calibration sources, but all power to the sources is off.
4. The fourth choice offsets are determined from the (approximately 30) samples of "cold" space which occur between the solar disk observation and the re-capture of the earth disk.

In cases where the first option is not viable, the second option is used, along with a linearly-fitted delta based upon the historical differences between method 1 and method 2. The offsets determined using options 3 and 4 have never been used in production processing.

5. Data Acquisition Methods:

The ERBE nonscanner instrument consists of four Earth-viewing detectors and one solar monitor detector located on the head assembly. The four Earth-viewing detectors are unchopped active cavity radiometers (ACR), whereas the solar monitor is an unfiltered chopped ACR designed to measure direct solar radiation for calibrating the Earth-viewing detectors. Two of these detectors have wide field-of-view (WFOV) apertures allowing the detectors to view the entire disk of the Earth; the other two detectors have medium field-of-view (MFOV) apertures allowing the detectors to view an area about 1000 km in diameter. Two of the Earth-viewing detectors, one WFOV and one MFOV, and the solar monitor detector measure total radiation, whereas the other two Earth-viewing detectors measure shortwave radiation. The total radiation detectors are unfiltered, and the shortwave spectral bands are achieved by use of fused silica dome filters placed over the detectors.

The nonscanner instrument microprocessor processes and executes ground-commanded and stored commands to direct and control the instrument operations. The instrument can operate in several modes so that radiation measurements can be made over a wide range of operational conditions. The instrument can operate at azimuth angles between 0 and 180 degrees, and at fixed elevation beam positions of 0(nadir), 78 (solar ports), and 180 (stow or internal calibration position) degrees. Normal Earth-viewing operation is at the nadir elevation position and at an azimuth position of 180 degrees for NOAA-10, 170 degrees for NOAA-9, and 0 degrees for ERBS. The ERBE nonscanner instrument output consists of a complete cycle of radiometric and housekeeping measurements every 16 seconds. There are 20 radiometric measurements every 16 seconds, while the frequency of housekeeping measurements is either 1, 2, or 4 measurements per 16 seconds, depending on the type of measurement.

Telemetry data from the ERBE instruments on the NOAA-9 and NOAA-10 spacecraft are transmitted to Control and Data Acquisition (CDA) ground stations at Gilmore Creek, Alaska, and Wallops Island, Virginia that relay the data through a geostationary communications satellite to the SOCC at NESDIS in Suitland, Maryland. NOAA provides decommutation processing of the telemetry data and provides the data to LaRC. During portions of the ERBE mission, telemetry data from the NOAA spacecraft were transmitted to GSFC for decommutation processing and delivery to LaRC. Telemetry and tracking data from the ERBE instrument on ERBS are transmitted to the NASA ground terminal at White Sands, New Mexico through the Tracking and Data Relay Satellite System (TDRSS). The data are transmitted from the ground terminal to the NASA communications center at GSFC, where the data are processed by the Information Processing Division (IPD) that provides ERBE data to LaRC.

6. Observations:

Data Notes:

Not applicable.

Field Notes:

Not applicable.

7. Data Description:

Spatial Characteristics:

Spatial Coverage:

The spatial coverage differs with the channel and the spacecraft, as described below.

WFOV Instruments: these two fixed detectors continuously view the earth disc (plus a small ring of space). The measurements are continuous over the entire globe for NOAA-9 and NOAA-10, and between 57 degrees north and south latitudes for ERBS which precesses approximately 3.95 degrees west per day.

MFOV Instruments: these two fixed detectors continuously view an area about 1000 km in diameter (nominally, a 5 degree earth central angle at the top of the Earth atmosphere, TOA). The measurements are continuous over the entire globe for NOAA-9 and NOAA-10, and between 57 degrees north and south latitude for ERBS.

Scanner Instruments: these three scanning instruments continuously view small areas over the entire Earth. The cross-track scan FOV is approximately 40 km at nadir, and there is a 35FOV overlap at nadir for ERBS between scans.

The ERBE instruments on board the NOAA-9 and NOAA-10 satellites provide global spatial coverage, while the scanner instruments on board the ERBS provides coverage between 67.5 degrees north and south latitude and the nonscanner instruments on board the ERBS provide coverage between 60 degrees north and south latitude.

Spatial Coverage Map:

Though a map is not available, the limits of coverage are discussed in the Spatial Coverage Section.

Spatial Resolution:

The spatial resolution differs with the four types of instruments and the two types of spacecraft (ERBS and NOAA). The WFOV instruments have 136 degree FOV on ERBS and 126 degree FOV on the NOAA satellites. The MFOV instruments have footprints of approximately 5 geocentric degree radius or 1000 km at the TOA. The scanner instruments have an instantaneous hexagonal FOV with an angular size of 3 X 4.5 degree, which is equivalent to a 31 X 47 km footprint at nadir for ERBS and 44 X 65 km for NOAA. The solar instrument has an unencumbered FOV which observes the entire solar disk.

Gridded products of the scanner data are available in 2.5 X 2.5 degree resolutions. S-4 and S-4G scanner data are also available as 5 X 5 degree and 10 X 10 degree nested grids. 5 X 5 degree resolution and 10 X 10 degree nested grids are available for numerical filter nonscanner data, and 10 X 10 degree resolution is available for the shape factor nonscanner data on the S-4 output product.

Projection:

Gridding is an equal-angle projection of 2.5 X 2.5 degree (NFOV, 10368 bins), 5.0 X 5.0 degree (MFOV, 2592 bins), and 10.0 X 10.0 degree (WFOV, 648 bins).

Grid Description:

Binning of the data is based on an equal-angle grid of 2.5 X 2.5 degree (NFOV, 10368 bins), 5.0 X 5.0 degree (MFOV, 2592 bins), and 10.0 X 10.0 degree (WFOV, 648 bins). In each resolution, the bin number 1 is found at 90 degree N, 0 degree W with the bin number increasing in an easterly direction.

Temporal Characteristics:

Temporal Coverage:

Instruments on the three satellites (ERBS, NOAA-9, and NOAA-10) began acquiring Earth viewing data in November 1984, February 1985, and October 1986, respectively. All of the scanner instruments outlived their life expectancy of one year. The NOAA-9 scanner ceased operations on January 20, 1987 and the NOAA-10 scanner on May 22, 1989. The ERBS scanner ceased operations on February 28, 1990. All of the Earth-viewing nonscanner instruments collect measurements continuously except during calibrations. The solar instrument collects about 20 minutes of usable data during regularly scheduled bi-weekly solar calibration periods. Additional solar measurement data are sometimes obtained for special projects.

Temporal Coverage Map:

Table 3 shows the archival status of the S-4G product. The various combinations of the satellites reflect the actual duration of the scanners as indicated in Table 3. Note that the MFOV data were not processed for the NOAA-10 satellite.

Please consult the Langley ASDC IMS for available data granules for both single and combination satellites.

Table 3: Archival Status of S-4G Products from 1984 to 1990

November 1984 - January 1985	ERBS
February 1985 - October 1986	ERBS/NOAA-9
November 1986 - January 1987	ERBS/NOAA-9/NOAA-10*

February 1987 - May 1989	ERBS/NOAA-10*
June 1989 - February 1990	ERBS

**MFOV data from NOAA-10 are not archived.*

Temporal Resolution:

Data records for the Level 2 products are instantaneous measurements and estimates. Gridded data (the S-9, S-10, S-4, and S-4G products) are daily, monthly hour (hourly averages for a month), monthly day (daily averages for a month), and hourly.

Data Characteristics:

Parameter/Variable:

For each satellite or combination of satellites, the data are stored in several different files based on the instrument (scanner or nonscanner); resolution (2.5, 5.0, or 10.0 degrees); and type of average (regional, zonal, or global). The scientific data item definitions are the same for both the scanner and the nonscanner. The main difference between the two formats is the presence of clear-sky data in the scanner files.

On the S-4G, each item is an integer quantity. These items are either a 32-, 16-, or 8-bit word depending on the data item. Because these data items are stored as integers, a scale factor is stored in the files, also according to word size. The scale factor is used as follows:

Real Data Quantity = (Integer Scaled Quantity from File) / (Scale Factor)

Table 4 and Table 5 provide a list of all of the data items, their HDF names, data type, bits size, scale factors, and minimum and maximum values.

The scientific data items are defined by data type: monthly(day), monthly(hour), daily, or monthly hourly.

Table 4: Scanner Output Data

Item Name	HDF Name	Data Type	Bits/Word	No. Values per Region	Scale Factor	Minimum Value	Maximum Value
TSOLRD	TSOLRD MN (DAY)	MONTHLY (DAY)	32	1	100	0	500000
$\overline{M}_{NET}$:	NET MN (DAY)	MONTHLY (DAY)	32	1	100	-200	200
$\overline{M}_{NET}$: $_{CS}$	NETCS MN (DAY)	MONTHLY (DAY)	32	1	100	-200	200
$TSOLRD_{CS}$	TSOLRDCS MN (DAY)	MONTHLY (DAY)	32	1	100	0	500000
$\overline{M}_{NET}$:	NET MN (HOUR)	MONTHLY (HOUR)	32	1	100	-200	200
TSOLRH	TSOLRH MN (HOUR)	MONTHLY (HOUR)	32	1	100	0	500000
$\overline{M}_{NET}$: $_{CS}$	NETCS MN (HOUR)	MONTHLY (HOUR)	32	1	100	-200	200
$TSOLRH_{CS}$	TSOLRHCS MN (HOUR)	MONTHLY (HOUR)	32	1	100	0	500000
SOLARD	SOLARD DAILY	DAILY	32	31	100	0	500000
SOLARH	SOLARH HOURLY	HOURLY	32	24	100	0	500000
$SOLARH_{CS}$	SOLARHCS HOURLY	HOURLY	32	24	100	0	500000
$\overline{M}_{LW}$:	LW MN (DAY	MONTHLY (DAY)	16	1	10	0	400
$\overline{M}_{SW}$:	SW MN (DAY)	MONTHLY (DAY)	16	1	10	0	800
ALBEDO	ALBEDO MN (DAY)	MONTHLY (DAY)	16	1	1000	0	1
$\overline{M}_{LW}$: $_{CS}$	LWCS MN (DAY)	MONTHLY (DAY)	16	1	10	0	400
$\overline{M}_{SW}$: $_{CS}$	SWCS MN (DAY)	MONTHLY (DAY)	16	1	10	0	800

$ALBEDO_{CS}$	ALBEDOCS MN (DAY)	MONTHLY (DAY)	16	1	1000	0	1
$\overline{M}_{LW}$	LW MN (HOUR)	MONTHLY (HOUR)	16	1	10	0	400
$\overline{M}_{SW}$	SW MN (HOUR)	MONTHLY (HOUR)	16	1	10	0	800
ALBEDO	ALBEDO MN (HOUR)	MONTHLY (HOUR)	16	1	1000	0	1
$\overline{M}_{LW\,CS}$	LWCS MN (HOUR)	MONTHLY (HOUR)	16	1	10	0	400
$\overline{M}_{SW\,CS}$	SWCS MN (HOUR)	MONTHLY (HOUR)	16	1	10	0	800
$ALBEDO_{CS}$	ALBEDOCS MN (HOUR)	MONTHLY (HOUR)	16	1	1000	0	1
$\overline{M}_{LW}$	LW DAILY	DAILY	16	31	10	0	400
$\overline{M}_{SW}$	SW DAILY	DAILY	16	31	10	0	800
ALBEDO	ALBEDO DAILY	DAILY	16	31	1000	0	1
$\overline{M}_{LW\,CS}$	LWCS DAILY	DAILY	16	31	10	0	400
$\overline{M}_{SW\,CS}$	SWCS DAILY	DAILY	16	31	10	0	800
$ALBEDO_{CS}$	ALBEDOCS DAILY	DAILY	16	31	1000	0	1
$\overline{M}_{LW}$	LW HOURLY	HOURLY	16	24	10	0	400
$\overline{M}_{SW}$	SW HOURLY	HOURLY	16	24	10	0	1000
ALBEDO	ALBEDO HOURLY	HOURLY	16	24	1000	0	1
$\overline{M}_{LW\,CS}$	LWCS HOURLY	HOURLY	16	24	10	0	400
$\overline{M}_{SW\,CS}$	SWCS HOURLY	HOURLY	16	24	10	0	1000
$ALBEDO_{CS}$	ALBEDOCS HOURLY	HOURLY	16	24	1000	0	1
ND_{LW}	NDLW DAILY	DAILY	8	31	1	0	24
ND_{SW}	NDSW DAILY	DAILY	8	31	1	0	24
$ND_{LW_{cs}}$	NDLWCS DAILY	DAILY	8	31	1	0	24
$ND_{SW_{cs}}$	NDSWCS DAILY	DAILY	8	31	1	0	24
NH_{LW}	NHLW HOURLY	HOURLY	8	24	1	0	31
NH_{SW}	NHSW HOURLY	HOURLY	8	24	1	0	31
$NH_{LW_{cs}}$	NHLWCS HOURLY	HOURLY	8	24	1	0	31
$NH_{SW_{cs}}$	NHSWCS HOURLY	HOURLY	8	24	1	0	31
GEOTYPE	GEOTYPE	MONTHLY	8	1	1	1	5

NOTE: CS at the end of an item name indicates that the item is for clear-sky conditions only.

Table 5: Nonscanner Output Data

Bytes	Description	Example	Note
1-2	Subsystem Indicator	7	The subsystem indicator for the S-4 Output Product will always be 7.
3-4	Product Code	1	The S-4 Output Product Subsystem has arbitrarily defined the product code for the tape to

			be 1 for scanner plus nonscanner processing S-4N, 2 for nonscanner only processing S-4N.
5-6	Spacecraft Indicator	2	A number 1-7 will apepar here depending upon whether data is for a single satellite or a combination of satellites. See Table 14.
7-8	Whole Julian date (high-order part)	244	The intial Julian date for this example is 2445700.50000 which corresponds to midnight on January 1, 1984.
9-10	Whole Julian date (low-order part)	5700	The whole Julian date for the first day of the month.
11-12	Fractional Julian date	5000	The fractional Julian date will be 0.5
13-14	Processed Version Counter	1	A value of 1 means that the S-4 product has been processed one time and not reprocessed.
15-16	Year Processed	85	For this example, the S-4 product was processed on February 3, 1985, at 9 p.m. $48^{M}54^{S}$.
17-18	Month Processed	2	
19-20	Day Processed	3	
21-22	Hour Processed	21	
23-24	Minute Processed	48	
25-26	Second Processed	54	
27-30	Spares	0	

Item Name	HDF Name	Data Type	Bits/Word	No. Values per Region	Scale Factor	Minimum Value	Maximum Value
GEOTYPE	GEOTYPE	MONTHLY	16	1	1000	0	1
ND_{LW}	NDLW DAILY	DAILY	8	31	1	0	24
ND_{SW}	NDSW DAILY	DAILY	8	31	1	0	24
NH_{LW}	NHLW HOURLY	HOURLY	8	24	1	0	31
NH_{SW}	NHSW HOURLY	HOURLY	8	24	1	0	31

Variable Description/Definition:

Monthly (Day) Quantities

Monthly (Day) Quantities: These are monthly means based on daily calculations of flux. For longwave (LW) quantities, the daily means are obtained from the extrapolation, interpolation, and diurnal modeling algorithms thatoperate on the existing longwave measurements. The extrapolation and interpolation algorithms will, in general, cross daily boundaries, but the longwave diurnal model applied to land scenes operates on a specific day.

The shortwave (SW) quantities are based on calculations for specific days. The days are defined to be symmetric about solar noon.

$\overline{M}_{SW}$: The monthly mean shortwave flux (SWF) based on daily SWF values, including "measurements" from the Inversion Subsystem (Reference 5) and modeled values, within this region (Wm^{-2}).

$$\overline{M}_{SW} = \bar{a} \cdot \sum_{d=1}^{N} S(d) / (24 \cdot N) \quad (1)$$

where N = all days of month.

$\overline{M}_{LW}$: The monthly mean longwave flux (LWF) based on all extrapolated, interpolated, and modeled LW values for the month in this region.

$$\overline{M}_{LW} = \sum_{d=1}^{N} \sum_{h=1}^{24} M_{LW}(d,h) / (24 \cdot N) \quad (2)$$

where N = all days of month.

- ALBEDO: The monthly mean albedo from daily values, based on the sum of all SWFs calculated for days with at least one SW measurement (D_{sw}).

$$\bar{\alpha} = 24 \cdot \sum_{D_{sw}} M_{SW}(d) / \sum_{D_{sw}} S(d) \quad (3)$$

where S(d) = integrated solar radiance.

The solar incidence is integrated from sunrise to sunset for each day with SW data, assuming a sun position for the day that is fixed at its position for $0^h0^m0^s$ UT. The summed SWF for each day is multiplied by the ratio of the integrated to summed solar incidence for that day to provide some corrections to the summation error.

$$\bar{M}_{SW}(d) = [S(d)/S'(d)] \cdot \sum_{h=1}^{24} M_{SW}(h)/24 \quad (4)$$

where S'(d) and S(d) are the summed and integrated solar radiances, respectively.

Other equations used to calculate the albedo values in S-4G may be found in the Calculated Variables Section of this document.

$\bar{M}_{NET}$: The monthly net flux defined from albedo in Monthly Time/Space Averaging, the sum of integrated solar incidence over the entire month, and monthly net LWF (Wm^{-2}).

$$\bar{M}_{NET} = \left[(1-\bar{\alpha}) \cdot \sum_{d=1}^{N} S(d)/(24 \cdot N)\right] - M_{LW} \quad (5)$$

- TSOLRD: The monthly total integrated solar incidence for all days of the month ($W\text{-}hm^{-2}$).

Monthly (day) values for clear-sky: The previous quantities are calculated from all data including clear, partly cloudy, mostly cloudy, and overcast conditions. Clear-sky information (identified with a CS subscript) for longwave (means and statistics defined in Reference 1) is calculated in the Inversion Subsystem and passed through Monthly Time/Space Averaging without modification. The shortwave clear-sky values are calculated by Monthly Time/Space Averaging according to the distribution of cloud conditions as indicated by the scene fraction vector.

Monthly (Hour) Values

Monthly (Hour) Quantities: These items are monthly means based on values averaged over the month at each local hour. In general, they result in different values for the same quantity, compared to the monthly (day) means.

$\bar{M}_{SW}$: The monthly mean SWF based on summing SWF values over days with at least one SW measurement, and then over each local hour (Wm^{-2}).

$$\bar{M}_{SW} = \bar{\alpha} \cdot \sum_{d=1}^{N} S(d)/(24 \cdot N) \quad (6)$$

where N = all days of month.

$\bar{M}_{LW}$: The monthly mean LWF based on extrapolated, interpolated, and modeled LW values only for days during the month that had at least one actual LW measurement (Wm^{-2}).

$$\bar{M}_{LW} = \sum_{h=1}^{24} M_{LW}(h)/24 \quad (7)$$

- ALBEDO: The monthly mean albedo from monthly hourly values, based on the sum of all SWFs calculated. There is no correction for integrated solar incidence in the monthly hourly albedo calculations. The equations used to calculate the albedo values in S-4G may be found in the Calculated Variables Section of this document.

$$\bar{\alpha} = 24 \cdot \sum_{D_{sw}} M_{SW}(d) / \sum_{D_{sw}} S(d) \quad (8)$$

where S(d) = integrated solar radiance, D_{sw} = days with at least one SW measurement.

$\bar{M}_{NET}$: The monthly net flux defined from albedo in Monthly Time/Space Averaging, the solar incidence summed (not integrated) over the entire month, and monthly net LWF defined from days with at least one LW measurement (Wm^{-2}).

$$\overline{M}_{NET}(mha) = (1-\bar{\alpha}) \cdot \sum_{d=1}^{N} S(d)/(24 \cdot N) - \overline{M}_{LW} \qquad (9)$$

where mha = monthly hourly average.

- TSOLRH: The monthly total solar incidence for all days of the month ($W\text{-}hm^{-2}$).

Monthly (hour) values for clear-sky: Clear-sky information for longwave (means and statistics defined in Reference 1) is based on values calculated in the Inversion Subsystem. The shortwave clear-sky values are calculated by Monthly Time/Space Averaging according to the distribution of cloud conditions as indicated by the scene fraction vector.

Daily Values

Daily values: These quantities are calculated for each day in the month.

$\overline{M}_{SW}$: The daily shortwave flux; i.e., the sum of all measured and modeled SWFs for every day with at least one SW measurement, corrected by the ratio of integrated to summed solar incidence (Wm^{-2}).

$$\overline{M}_{SW}(d) = [S(d)/S'(d)] \cdot \sum_{h=1}^{24} M_{SW}(h)/24 \qquad (10)$$

where S(d) and S'(d) are the integrated and summed solar radiances, respectively.

$\overline{M}_{LW}$: Daily LWF consisting of measurements and extrapolated, interpolated, and modeled values (Wm^{-2}).

- ALBEDO: The daily albedo is defined as the ratio of daily SWF to the integrated daily solar incidence. The equations used to calculate the albedo values in S-4G may be found in the Calculated Variables Section of this document.
- TSOLRD: The integrated solar incidence for a day that includes at least one SW measurement ($W\text{-}hm^{-2}$).
- ND_{SW}: The number of hours with SW measurements for a day that includes at least one SW measurement.
- ND_{LW}: The number of hours with LW measurements for a day that includes at least one LW measurement.

Daily values for clear-sky: The above values are repeated for clear-sky conditions (except for the SOLARD). The LW clear-sky values are passed from the Inversion Subsystem, but the SW values are calculated within Monthly Time/Space Averaging.

Monthly Hourly Values

Monthly hourly values: These values are calculated for the month at each local hour.

$\overline{M}_{SW}$: The monthly average SWF at this hour (Wm^{-2}).

$\overline{M}_{LW}$: The monthly average LWF at this hour (Wm^{-2}).

- ALBEDO: Monthly hourly albedo. The equations used to calculate the albedo values in S-4G may be found in the Calculated Variables Section.
- SOLARH: The integrated solar incidence over those days with SW data for a given hour ($W\text{-}hm^{-2}$).
- NH_{SW}: The number of days that contain SW measurements for a given hour.
- NH_{LW}: The number of days that contain LW measurements for a given hour.

Monthly hourly values for clear-sky: The above values are repeated for clear-sky conditions as defined by the Inversion Subsystem.

Geotype

Scanner:
An integer from 1-5 denoting the surface type for the region. The types are:

1 = ocean
2 = land
3 = snow
4 = desert
5 = land/ocean mix (coastal regions)

For the land/ocean mix, the corresponding directional models (clear, partly, or mostly cloudy over this scene) are linear composites of land and ocean models and not independent models.

Nonscanner:
The fraction of cloud-free (as determined by the Inversion Subsystem) land and desert geotype. If greater than 0.5, the half-sine model is applied in the calculation of LWF (Reference 1).

Unit of Measurement:

Units of measurement for the calculated and measured science variables for the S-4G data product can be found in the Variable Description/Definition.

Data Source:

The purpose of the S-4G Output Product is to provide averages of radiant flux values and albedos using data from the Monthly Time/Space Averaging Subsystem (Reference 3) on a regional, zonal, and global basis.

The S-4G product contains data which have been averaged to 2.5, 5.0, and 10.0 grid scales. The layout of a 2.5 degree system is given; the 5.0 and 10.0 systems are designed similarly. In this grid system, L = longitude and λ = latitude is replaced with colatitude, where $\lambda_{co} = 90 - \lambda$, so that $0° <= \lambda_{co} <= 180°$.

The following list shows the number of regions for each resolution:

Resolution	Total No. Regions
2.5	10,368
5.0	2,592
10.0	648

To facilitate comparison with nonscanner data, the scanner data are nested with area weighting to 5.0 and 10.0 regions, with four scanner 2.5 regions producing a 5.0 region and sixteen 2.5 regions producing a 10.0 region. Similarly, four nonscanner numerical filter 5.0 regions are nested to produce a 10.0 region. This nesting is pictured in Figure 2, and the weighting is described further on in this section.

The S-4G product also contains averages over the latitudinal bands (zones). The following list shows the number of latitudinal bands for each resolution:

Resolution	Total No. Bands	Total No. of Regions in Each Band
2.5	72	144
5.0	36	72
10.0	18	36

The final type of average is on a global level. Each parameter is averaged over the entire globe with area weighting.

The equation 11 gives the formula for calculating averages:

$$\mathbb{M} = \frac{\sum_{i=1}^{N} W_i M_i}{\sum_{i=1}^{N} W_i} \quad (11)$$

where,

$\mathbb{M}$ = nested average flux value
N = number of regions included in nested average

W_i = area weighting factor
M_i = individual values

For each of the three ERBE spacecraft, (ERBS, NOAA-9, and NOAA-10), there can be three sets of measurements (scanner, nonscanner MFOV, and nonscanner WFOV). For the nonscanner measurements, there are two data reduction techniques (shape factor and numerical filter). For each satellite, the on-line processing proceeds as follows:

1. Scanner - 2.5 resolution
2. Nonscanner MFOV - 5.0 degree resolution (numerical filter)
3. Nonscanner WFOV - 5.0 degree resolution (numerical filter)
4. Nonscanner MFOV - 10.0 degree resolution (shape factor)
5. Nonscanner WFOV - 10.0 degree resolution (shape factor)

Processing is controlled by the lower resolution region numbers. A simple set of calculations can be used to derive the four higher resolution region numbers which will be nested into the lower resolution region. The formulas for finding the four 2.5 degree region box numbers which are nested into a 5.0 degree region box are:

$B_{2.5}(1) = 288 \text{ INT } [(B_5 - 1)/72] + 2 \text{ MOD } [(B_5 - 1),72] + 1$

$B_{2.5}(2) = B_{2.5}(1) + 1$

$B_{2.5}(3) = B_{2.5}(1) + 144$

$B_{2.5}(4) = B_{2.5}(1) + 145$

where,

$B_{2.5}(N)$	= 2.5° region box number
B_5	= 5° region box number

The formulas for finding the four 5.0 degree region box numbers which are nested into a 10.0 degree region box are:

$B_5(1) = 144 \text{ INT } [(B_{10} - 1)/36] + 2 \text{ MOD } [(B_{10} - 1),36] + 1$

$B_5(2) = B_5(1) + 1$

$B_5(3) = B_5(1) + 72$

$B_5(4) = B_5(1) + 73$

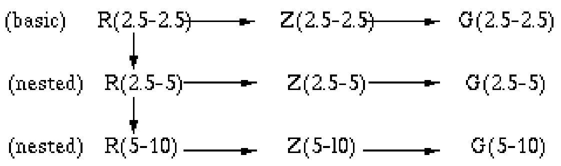
where,
$B_{10}(N)$ = 10.0° region box number

The colatitude index is used to obtain the correct area weighting value and to distinguish between polar latitudinal bands and nonpolar latitudinal bands. It can be derived from the region number as follows:

COLAT = $\text{INT}[B_6 - 1)/N] + 1$

where,
B_6 = higher resolution region number
N = number of regions in a latitudinal band

The 2.5 degree product is used to nest the 5.0 degree product which is then used to nest to the 10.0 degree product. This process is done for each satellite and each combination of satellites. For each of these processes, separate zonal and global products are produced for each resolution,



where for any data product, $R(r_1 - r_2)$, $r_1 - r_2$ designates the source and final product resolution. Analogously, there will also be similar paths for numerical filter data:

(basic) R(MFOV,5-5) → Z(MFOV,5-5) → G(MFOV,5-5)
↓
(nested) R(MFOV,5-10) → Z(MFOV,5-10) → G(MFOV, 5-10)

and

(basic) R(WFOV,5-5) → Z(WFOV,5-5) → G(WFOV,5-5)
↓
(nested) R(WFOV,5-10) → Z(WFOV,5-10) → G(WFOV,5-10)

and for shape factor data:

(basic) R(MFOV,10-10) → Z(MFOV,10-10) → G(MFOV,10-10)

and

(basic) R(WFOV,10-10) → Z(WFOV,10-10) → G(WFOV,10-10)

So, for each satellite and combination of satellites, there are potentially nine different global (monthly) averages of each calculated quantity. Why is there a difference between, for example, G(2.5-2.5) and G(2.5-5)? If there were no missing data on the high resolution grid, these numbers should be the same. However, missing data forces nesting procedures which can produce some discrepancies between the two products.

Because the ERBE grid system divides the globe into regions which are defined by equal increments of latitude and longitude rather than equal areas, the nested averages must be normalized by weighting each region based upon its area. Since regions across a latitudinal band have the same area, only one weighting factor is needed for each latitudinal band. It also follows that since the area weighting factors across a latitudinal band are the same, the zonal averages do not have to be normalized. Equation 12 gives the formula for calculating the area weighting factors.

$$W_i = \frac{\pi R^2}{90}\Delta\theta \sin\left(\frac{\Delta\theta}{2}\right) \sin\theta_c$$

where,
W_i = area of $\Delta\theta$ by $\Delta\theta$ region in km^2
$\Delta\theta$ = resolution in degrees (2.5, 5.0, 10.0)
R = distance from the center of the Earth to the top-of-the atmosphere (km)
θ_c = colatitude in degrees of the center of the latitudinal band region

Polar day-night indicators are used to identify those regions within approximately 23.5 degrees of the poles that experience continuous darkness or continuous daylight at certain times of the year. These regions are treated differently from those which always experience day-night cycles.

In general, radiant flux values for regions not observed by the satellite are not accumulated as part of the averaging process. However, since it is known that the shortwave radiant flux is zero when there is no daylight, those unobserved regions which are in complete darkness for the entire month (i.e., near the polar regions at certain times of the year), will have the shortwave set to zero. The reason for doing this is to reduce the error in the zonal and global averaging process.

There is a direct relationship between the daily solar declination and the colatitude of a region. This can be used to determine whether or not that region is experiencing total darkness or has some daylight and which part of the month is affected. Of course, none of this has any effect on regions in latitudinal bands which are not near the north or south poles.

The criteria for setting the polar day-night indicators for latitudes in the northern hemisphere are:

1. April through August are daylight months.
2. For the other months (January through March and September through December), if the magnitude of the **negative** solar declination is greater than the center colatitude, then the region is in darkness for that day.
3. For months during which some days are in darkness and others are not: if the month is January through March, then the days before the flagged day are in darkness; if the month is September through December, then the days after the flagged day are in darkness.

The criteria for setting the polar day-night indicators for latitudes in the southern hemisphere are:

1. January, February, and October through December are daylight months.
2. For the other months (March through September), if the **positive** solar declination is greater than (180 degrees - center colatitude), then the day is in darkness.
3. For months during which some days are in darkness and others are not: if the month is March through May, then the days after the flagged day are in darkness; if the month is July through September, then the days before the flagged day are in darkness.

In order to clarify this concept, some tables have been provided to illustrate the results of applying the logic described above. Table 6 shows which colatitudes are considered to be the northern and southern polar latitudes for each resolution. Table 7 shows the solar declinations for 1985, which was chosen as the example year. Table 8 shows the sunlit days for the northern and southern polar regions for the 2.5 degree resolution. Table 9 gives a sample of the polar day-night indicator values for some latitudes at the 2.5 degree resolution.

Table 6: Polar Colatitude Indicators and Center Colatitudes

2.5 DEGREE RESOLUTION		
Colat. Indicators	**Center Colat. (Deg.)**	**Hemisphere**
1	1.25	North
2	3.75	
3	6.25	
4	8.75	
5	11.25	
6	13.75	
7	16.25	
8	18.75	
9	21.25	
64	158.75	South
65	161.25	
66	163.75	
67	166.25	
68	168.75	
69	171.25	
70	173.75	
71	176.25	
72	178.75	

5.0 DEGREE RESOLUTION		
Colat. Indicators	**Center Colat. (Deg.)**	**Hemisphere**
1	2.50	North
2	7.50	
3	12.50	
4	17.50	
5	22.50	
32	157.50	South
33	162.50	
34	167.50	
35	172.50	
36	177.50	

10.0 DEGREE RESOLUTION		
Colat. Indicators	**Center Colat. (Deg.)**	**Hemisphere**
1	5.00	North
2	15.00	
17	165.00	South
18	175.00	

Table 7: 1985 Solar Declinations

DAYS	MONTHS											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	-23.02	-17.17	-7.68	4.44	15.00	22.02	23.13	18.09	8.38	-3.08	-14.34	-21.76
2	-22.94	-16.89	-7.30	4.82	15.30	22.15	23.06	17.83	8.02	-3.47	-14.66	-21.92
3	-22.85	-16.60	-6.92	5.21	15.60	22.28	22.98	17.58	7.65	-3.86	-14.98	-22.06
4	-22.75	-16.30	-6.54	5.59	15.89	22.40	22.90	17.31	7.28	-4.24	-15.29	-22.20
5	-22.64	-16.00	-6.15	5.97	16.18	22.52	22.81	17.05	6.91	-4.63	-15.60	-22.33
6	-22.53	-15.70	-5.77	6.35	16.46	22.63	22.72	16.77	6.54	-5.01	-15.90	-22.46
7	-22.40	-15.39	-5.38	6.73	16.74	22.73	22.62	16.50	6.17	-5.40	-16.20	-22.58
8	-22.28	-15.07	-4.99	7.10	17.02	22.82	22.51	16.22	5.79	-5.78	-16.49	-22.69
9	-22.14	-14.75	-4.60	7.48	17.29	22.91	22.39	15.93	5.42	-6.16	-16.78	-22.79
10	-22.00	-14.43	-4.21	7.85	17.55	22.99	22.27	15.64	5.04	-6.54	-17.07	-22.89
11	-21.84	-14.11	-3.82	8.22	17.81	23.07	22.14	15.35	4.66	-6.92	-17.35	-22.98
12	-21.69	-13.78	-3.42	8.59	18.07	23.13	22.01	15.05	4.28	-7.30	-17.62	-23.06
13	-21.52	-13.44	-3.03	8.95	18.32	23.20	21.87	14.75	3.90	-7.67	-17.89	-23.13
14	-21.35	-13.11	-2.64	9.31	18.56	23.25	21.72	14.45	3.52	-8.05	-18.16	-23.20
15	-21.17	-12.77	-2.24	9.67	18.80	23.30	21.57	14.14	3.13	-8.42	-18.42	-23.25
16	-20.98	-12.42	-1.85	10.03	19.04	23.34	21.41	13.82	2.75	-8.79	-18.67	-23.30
17	-20.79	-12.07	-1.45	10.38	19.27	23.37	21.24	13.51	2.36	-9.15	-18.92	-23.35
18	-20.59	-11.72	-1.05	10.73	19.49	23.40	21.07	13.19	1.97	-9.52	-19.16	-23.38
19	-20.39	-11.37	-.66	11.08	19.71	23.42	20.90	12.86	1.59	-9.88	-19.40	23.41

20	-20.18	-11.01	-.26	11.43	19.92	23.43	20.71	12.54	1.20	-10.24	-19.63	-23.43
21	-19.96	-10.65	.13	11.77	20.13	23.44	20.52	12.21	.81	-10.60	-19.86	-23.44
22	-19.73	-10.29	.53	12.11	20.33	23.44	20.33	11.87	.42	-10.96	-20.07	-23.44
23	-19.50	-9.92	.92	12.44	20.53	23.43	20.13	11.54	.03	-11.31	-20.29	-23.44
24	-19.27	-9.56	1.31	12.78	20.72	23.42	19.92	11.20	-.36	-11.66	-20.49	-23.42
25	-19.03	-9.19	1.71	13.10	20.90	23.40	19.71	10.85	-.75	-12.01	-20.70	-23.40
26	-18.78	-8.81	2.10	13.43	21.08	23.37	19.50	10.51	-1.14	-12.35	-20.89	-23.38
27	-18.52	-8.44	2.49	13.75	21.25	23.33	19.27	10.16	-1.53	-12.69	-21.08	-23.34
28	-18.26	-8.06	2.88	14.07	21.42	23.29	19.05	9.81	-1.92	-13.03	-21.26	-23.30
29	-18.00	-18.00	3.27	14.38	21.58	23.24	18.81	9.45	-2.31	-13.36	-21.43	-23.24
30	-17.73	-17.73	3.66	14.69	21.73	23.19	18.58	9.10	-2.69	-13.69	-21.60	-23.18
31	-17.45	-17.45	4.05	4.05	21.88	21.88	18.33	8.74	8.74	-14.02	-14.02	-23.12

Table 8: Sunlit Days for Northern and Southern Polar Regions

Year: 1985; Resolution: 2.5 deg.				
Hemisphere	**Colat. Indicator**	**Center Colat. (Deg.)**	**First Date for Sunlight**	**Last Date for Sunlight**
North	1	1.25	03/18	09/26
	2	3.75	03/12	10/02
	3	6.25	03/05	10/09
	4	8.75	02/27	10/15
	5	11.25	02/20	10/22
	6	13.75	02/13	10/30
	7	16.25	02/05	11/07
	8	18.75	01/27	11/16
	9	21.25	01/15	11/27
South	64	158.75	07/17	05/26
	65	161.25	07/30	05/14
	66	163.75	08/08	05/05
	67	166.25	08/17	04/26
	68	168.75	08/24	04/19
	69	171.25	08/31	04/12
	70	173.75	09/07	04/05
	71	176.25	09/14	03/30
	72	178.75	09/20	03/23

Table 9: Polar Day-Night Indicator Values for 1985 (2.5 Degree Resolution)

COLAT	**CENTER COLAT (Deg.)**	**POLAR FLAG**											
		JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
1	1.25	50	50	-18	0	0	0	0	0	26	50	50	50
3	6.25	50	50	-5	0	0	0	0	0	0	9	50	50
5	11.25	50	-20	0	0	0	0	0	0	0	22	50	50
7	16.25	50	-5	0	0	0	0	0	0	0	0	7	50
9	21.25	-15	0	0	0	0	0	0	0	0	0	27	50
64	158.75	0	0	0	0	26	50	-17	0	0	0	0	0
66	163.75	0	0	0	0	5	50	50	-8	0	0	0	0
68	168.75	0	0	0	19	50	50	50	-25	0	0	0	0
70	173.75	0	0	0	5	50	50	50	50	-7	0	0	0
72	178.75	0	0	23	50	50	50	50	50	-20	0	0	0

Data Range:

The S-4G output product consists of a maximum of fourteen data sets for each month: four scanner data sets and ten nonscanner data sets. The number of files per month may be less depending upon the instruments which are operational in a given month. Please refer to the Temporal Coverage Map Section of this document for the archival status of this product.

When the user is connected to the on-line Langley ASDC system, he will be able to select a particular data set pertaining to the type of ERBE S-4G data he is interested in. Column 1 of Table 10 lists the names of data sets which the user will see as he orders his data from the ASDC. Column 2 represents the names of the files of the data that the user will receive from the ASDC. Column 3 gives a description of each data set.

Table 10: HDF Data Sets Produced for Each S-4G Data Month

Data Sets	Data Filename*	Description of Data Set
ERBE_S4G_SC_2.5	s4g_sc2.5_yymm_s	Scanner 2.5 deg. regional averages
ERBE_S4G_SC_NEST5	s4g_sc5.0_yymm_s	Scanner 2.5 deg. nested to 5.0 deg. regional averages
ERBE_S4G_SC_NEST10	s4g_sc10_yymm_s	Scanner 5.0 deg. nested to 10.0 deg. regional averages
ERBE_S4G_SC_ZG	s4g_sc_zg_yymm_s	Scanner 2.5, 5.0, and 10.0 deg. zonal and global averages
ERBE_S4G_MFOV_NF	s4g_mnf5_yymm_s	Nonscanner medium field-of-view numerical filter 5.0 deg. regional averages
ERBE_S4G_MFOV_NF_N10	s4g_mnf10_yymm_s	Nonscanner medium field-of-view numerical filter 5.0 deg. nested to 10.0 deg. regional averages
ERBE_S4G_MFOV_NF_ZG	s4g_mnfzg_yymm_s	Nonscanner medium field-of-view numerical filter 5.0 and 10.0 deg. zonal averages and global averages
ERBE_S4G_MFOV_SF	s4g_msf10_yymm_s	Nonscanner medium field-of-view shape factor 10.0 deg. regional averages
ERBE_S4G_MFOV_SF_ZG	s4g_msfzg_yymm_s	Nonscanner medium field-of-view shape factor 10.0 deg. zonal and global averages
ERBE_S4G_WFOV_NF	s4g_wnf5_yymm_s	Nonscanner wide field-of-view numerical filter 5.0 deg. regional averages
ERBE_S4G_WFOV_NF_N10	s4g_wnf10_yymm_s	Nonscanner wide field-of-view numerical filter 5.0 deg. nested to 10.0 deg. regional averages
ERBE_S4G_WFOV_NF_ZG	s4g_wnfzg_yymm_s	Nonscanner wide field-of-view numerical filter 5.0 and 10.0 deg. zonal averages and global averages
ERBE_S4G_WFOV_SF	s4g_wsf10_yymm_s	Nonscanner wide field-of-view shape factor 10.0 deg. regional averages
ERBE_S4G_WFOV_SF_ZG	s4g_wsfzg_yymm_s	Nonscanner wide field-of-view shape factor 10.0 deg. zonal and global averages

** yy represents the year (e.g., 89 - 1989); mm represents the number value of a month (e.g., 01 = January, 12 = December)*

s represents the satellite code:
1 = NOAA-9
2 = ERBS
3 = NOAA-10
4 = NOAA-9/NOAA-10
5 = ERBS/NOAA-9
6 = ERBS/NOAA-10
7 = NOAA-9/ERBS/NOAA-10

Sample Data Record:

ERBE data records are quite large (on the order of 104 or 105 binary bytes per record). Reproducing sample records of this size in a document of this sort is impractical.

8. Data Organization:

Data Granularity:

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

Each archived granule contains data of a defined spatial resolution, as described in Table 10, for one month.

Data Format:

There are two descriptive text items stored in each HDF file to generally describe the data.

File ID: Describes the data in the file with respect to instrument, resolution, and type of average. Also described are the year and month (in yymm form) in which the data were acquired by the instruments and the satellite(s) which collected the data. (Example: ERBE S-4G 2.5 Degree Regional Scanner Data for 8411 ERBS)

File Description: Detailed description about the data that indicates the following:

- **Source:** Agency where the data were processed
- **Processing Data:** The date that the product was generated (in the form DD-MMM-YY) (e.g., 01-JAN-89)
- **Reference:** Reference Material Related to the product
- **Abstract:** Description of data in the HDF file, similar to the File ID
- **Missing Data:** Indicates values for missing data as follows:

  There are two types of missing data values, each based on the word size of the data. Missing regions are those regions which were not observed by the satellite. Missing data items are those regions which were observed by the satellite, but the data did not contain measurements for those data items.

  The default values for all missing data items are listed in Table 11.

  Table 11: Default Values for all Missing Data Items

No. Bits per Word	Missing Data Items Default Value	Missing Regions
32	2147483647 (S-4G)	-32767
16	32767	-32767
8	127	-127

- **Deadscanner Flags:** Because the scanner on the ERBS, NOAA-9, and NOAA-10 satellites became inoperative at different times, deadscanner flags were defined to inform the user whether the scanners were operating for each satellite for a particular data month. Three 1-byte character elements represent the NOAA-9, ERBS, and NOAA-10 deadscanner flags, respectively. The values are:

  0 - operative scanner
  1 - inoperative scanner
  2 - fill value signifying live scanner data which was processed before the deadscanner option was implemented, or no data for that satellite

- **HDF Notes to Users:** Describes to user any information that may be needed to correctly obtain the data from the HDF file.
- **Dimension Attributes:** The data are stored in the HDF file as a latitude/longitude grid. Labels, units, formats, and scales for each dimension are stored. For example, the S-4G 2.5 degree regional scanner data are stored as a two-dimensional array (72 x 144). The labels for each dimension are latitude and longitude with degrees as the appropriate units. The format is the format of the scales, in this case F6.1. The scales are the latitude and longitude bands (-90 to 90 degree) and (-180 to 180 degree) by 2.5 degrees.

For each parameter the following information is stored in the HDF file.

- **Label:** Describes the data measurements (e.g., Longwave, Shortwave, Clear-Sky, etc.); the type of data (monthly(hour), monthly(day), daily, or hourly); the spatial resolution of the data (2.5 degree, 5.0 degree, 10.0 degree); and whether they are regional, zonal, or global averages.
- **Units:** Describes the physical units of the measurement (e.g., Wm^{-2} for watts per square meter, or $W\text{-}hm^{-2}$ for watt hours per square meter).
- **Format:** The format (as specified in FORTRAN) of the data after the scale factor has been applied (e.g., F13.4).
- **Minimum Value:** The minimum range for data values for a given parameter.
- **Maximum Value:** The maximum range for data values for a given parameter.
  - Note: S-4G maximum values given for longwave and shortwave are incorrect. See Table 4 for correct values.
- **Annotation:** Describes the data measurements (e.g., Longwave, Shortwave, Clear-sky, etc.) and the type of data (monthly (hour),

monthly (day), daily or hourly) in abbreviated form. The abbreviated form of the annotation information on the S-4G has been written in an expanded form on the S-4GN.

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

There are a number of steps in the processing of the ERBE data. The mathematics involved in each of these steps is beyond the scope of this document. However, interested readers are referred to the following: NASA Reference Publication 1184, *Angular radiation models for Earth-atmosphere system, Volume 1: Shortwave radiation*, and *Volume 2: Longwave radiation*; NASA Technical Paper 2670, *Calculation and accuracy of ERBE scanner measurement locations*; and Smith (Reference 13).

Data Processing Sequence:

Processing Steps:

The S-4G product is an alternative to the original ERBE S-4 product (Reference 12).

The input to the standard S-4 product is provided by the Monthly Time/Space Averaging Subsystem, which accumulates data for each region into a 32x25 matrix. There is a 31x24 submatrix within the larger matrix with each row representing one day of the month and each column representing a local hour for the region. The 25th column contains the daily averages for the month, referred to as the daily averages. The 32nd row contains the hourly averages for the month, referred to as the monthly hourly averages. The lower right-hand box contains the average of the daily averages, referred to as the monthly (day) average, and the average of the monthly hourly averages, referred to as the monthly (hour) average. The daily, monthly hourly, monthly (day), and monthly (hour) averages are calculated and stored in a regional average data base in the Monthly Time/Space Averaging Subsystem and passed to the S-4 Output Products Subsystem (Reference 6). These values are used to provide the nested, zonal, and global averages mentioned earlier.

Up to five separate types of data can be received from Monthly Time/ Space Averaging. One or more (up to four) of these types of data may be missing without upsetting the processing. The five different types of data are:

1. NFOV; narrow field-of-view (2.5 degree resolution)
2. MFOV-NF; medium field-of-view - numerical filter (5.0 degree resolution)
3. WFOV-NF; wide field-of-view - numerical filter (5.0 degree resolution)
4. MFOV-SF; medium field-of-view - shape factor (10.0 degree resolution)
5. WFOV-SF; wide field-of-view - shape factor (10.0 degree resolution)

The Langley Research Center (LaRC) has the responsibility of processing and validating all science data from the ERBE mission and of distributing the resulting data products to the science community. The ERBE data processing system at LaRC uses a modular software subsystems approach to process the ERBE data, starting with the input telemetry and ephemeris data from Goddard Space Flight Center (GSFC) and NOAA and ending with the production of the required science data products.

The diagram in the Flowchart Figure shows the major steps in the science data processing, together with the primary input and output data products. The first step in this processing procedure is to ingest 24 hours of telemetry data from the ERBS, NOAA-9, or NOAA-10 spacecraft into the front-end processing subsystem of the Data Processing System. The processing at this step accounts for spacecraft differences and for differences in the data acquisition and handling systems of the ERBS and TIROS N satellites. The data are organized into a format that is common to data from GSFC and NOAA. Extensive data quality editing and evaluation are performed, including the checking of quality flags appended by the tracking networks and processing systems at GSFC and NOAA. The operational status of the instruments is determined, and all instrument housekeeping data and selected spacecraft housekeeping measurements are converted to engineering units and edited. Pointing vectors for the optical axes of the detectors are calculated in a local horizon coordinate system at the spacecraft.

The 8-day ephemeris data sets are processed and validated separately before combining them with the corresponding telemetry data. Orbital data are tested for consistency with data from the previous week, and tests are performed to verify the consistency of the orbit calculations between 1-minute data points. The tests include checks for in-plane and out-of-plane consistency and precision. The routine verification processing and other analyses performed to verify the accuracy of the ephemeris data have generally demonstrated accurate orbit determination for both the ERBS and NOAA spacecraft.

The next major processing stage begins with the merging of the output data from telemetry processing with data output from the ephemeris processing. The FOV locations on a surface at the TOA are determined for every radiometric measurement. The FOV locations are more critical for the scanner measurements than those of the nonscanner because of the small FOV of the scanner instrument. A FOV accuracy analysis has shown that the calculated locations of the scanner measurements are well within the FOV footprint of the instrument on the Earth.

At this processing stage, the raw measurements for each radiometric detector are also converted to incident radiances at the spacecraft. The conversion algorithms employ calibration coefficients that are based primarily on ground-based calibration data, but which are updated with results from in-flight calibrations.

In the inversion processing stage, data from the scanner detectors are used to identify the type of scene or source at the TOA that produced the raw radiometric measurements. Based on the scene type and geographical location, the scanner measurements are adjusted to account for changes in the spectral response in each detector. Using the selected scene-type, one of several angular directional models is selected for inverting or reducing the measurements from satellite altitude to radiant fluxes at the TOA. The nonscanner measurements are inverted using scene information determined during scanner data processing and two different inversion algorithms. One algorithm employs geometric shape factors and the other employs numerical filtering. An archival product, called the Processed Archival Tape (PAT), is produced at this point to retain detailed time histories of estimates of the radiant fluxes at the TOA.

The time-ordered estimates of TOA fluxes are sorted into spatial sequences for both the scanner and nonscanner measurements, grouping all estimates for a month together on a regional basis. A full calendar month of estimates is then retrieved for each region of the Earth. Hourly, daily, and monthly estimates of several different parameters are derived by interpolation using directional models that describe the temporal variation of the radiation budget components. Archival products of monthly averages of radiation components for both the scanner and nonscanner are produced at this point.

Several archival products are produced at the final stage of data processing. The nested averages product gives values of the scanner and nonscanner fluxes from each instrument averaged over various spatial scales. The processing at this stage also combines data from all available spacecraft to produce a combined-satellite product of TOA fluxes averaged over the same spatial scales. An archival product for solar monitor measurements is also produced to provide time histories of solar calibration data. Finally, a scene validation product is produced that combines ERBE data with measurements from the AVHRR and the HIRS instruments. Data from these two NOAA instruments are used to validate the scene identification algorithm. All archival data products are distributed first to the ERBE Science Team for review and validation and then to LaRC ASDC for archival.

Processing Changes:

Processing changes are described in the Special Corrections/Adjustments Section below.

Calculations:

Special Corrections/Adjustments:

Since the publication of Reference 12, several modifications have been made to Monthly Time/Space Averaging Algorithms which affected the S-4G product in the following areas:

1. Monthly Shortwave Averages

   Monthly shortwave averages are calculated using the monthly mean albedo and the sum of the integrated daily solar incidence of all days (N) of the month:

   $$\overline{M}_{SW} = \bar{\alpha} \cdot \sum_{d=1}^{N} S(d) / (24 \cdot N) \qquad (6)$$

   ($\bar{\alpha}$, and S(d) are defined in Reference 12)

2. Monthly Average Values

   An alternate definition of monthly average values may be expressed in terms of monthly hourly averages. In this case, calculate the average for each of the 24 local hours using only the days with measurements and then take the mean of the local hour averages. The calculation of the monthly hourly average albedo and SWF are the same as Equation 12 (Reference 1) and Equation 6 respectively, whether one first sums through the days or the hours of the month. Obviously, shortwave interpolation cannot take place on a given day if there are no shortwave measurements for that day.

3. Monthly Net Values

   In general, $\overline{M}_{NET}(mha)$ is not equal to $\overline{M}_{NET}$ as defined by Equation 18 (Reference 1) and Equation 13 (Reference 1) respectively, differing by the usage of the longwave interpolated values on days for which there were no longwave measurements. This difference can be significant if several days of measurements are missing. If there are no shortwave measurements for a given month and the monthly total integrated solar incidence is greater than zero, the solar and net parameters of these regions are not used in the global averages. Some of these regions lie on the latitude belt where the solar terminator occurs with the seasonal movement of the solar declination. Naturally, if the monthly total integrated solar incidence equals zero, the shortwave portion of Equation 18 (Reference 1) and Equation 13 (Reference 1) is zero. The sampling problems outlined in this paragraph will ultimately have to be dealt with outside the context of ERBE operational software.

4. Clear-sky Longwave Flux

   The shortwave parameters of the monthly clear-sky averages are the same as the monthly averages, except that clear-sky measurements are used. The same holds true for the longwave parameters for ocean, snow, and coast geotypes. Over land and desert geotypes, however, the lack of clear-sky longwave measurements on a daily basis or even on a monthly time-scale as in tropical convective regions, discourage any type of daily modeling. Therefore, a half-sine model is best applied after the clear-sky longwave measurements have been sorted by local hour. This will better account for the clear-sky diurnal variation, assuming that the clear-sky longwave diurnal range exceeds the day-to-day fluctuations for a given local hour. This way, the bias toward either daytime or night time clear-sky measurements have been reduced. First, the monthly hourly LWF MLW(h) as defined by Equation 16 (Reference 1) is calculated, but only clear-sky longwave measurements are used. The same conditions as defined by the LW half-sine model section apply, except that the least squares fit is weighted by the number of measurements for the local hour, and the night time average is the mean of all night time clear-sky longwave measurements. This method is used for both the monthly daily and monthly hourly clear-sky longwave averages for land and desert regions.

An additional change was made to the clear-sky averaging algorithm that corrects the misclassification of nighttime clear pixels as partly cloudy. For each nighttime hour box over land regions, a new clear-sky percentage is estimated by assuming that 100f the pixels classified as clear and partly cloudy are actually clear. If this new clear percentage exceeds 5 and represents an increase over the original clear-sky percentage, then the clear-sky longwave flux is recalculated using the mean and standard deviation of the total longwave flux.

5. Normalized Directional Models (See Table 12)

Table 12: Normalized Directional Models

	Solar Zenith Angle Bin Number										
Scanner Index	**0.95**	**0.85**	**0.75**	**0.65**	**0.55**	**0.43**	**0.35**	**0.25**	**0.15**	**0.05**	**Nonscanner Index**
(Clear) 1	1.00000	1.07895	1.19737	1.32895	1.51316	1.75000	2.11842	2.67105	3.52632	4.39474	1 (Ocean)
2	1.00000	.97813	1.01875	1.04375	1.09375	1.16438	1.28125	1.44375	1.68750	2.03750	2 (Land)
3	1.00000	1.00450	1.00899	1.01289	1.01588	1.01738	1.01514	1.00525	.97437	.92747	3 (Snow)
4	1.00000	1.02000	1.04800	1.08300	1.12600	1.17600	1.23400	1.30000	1.37200	1.45300	4 (Desert)
5+	1.00000	1.01059	1.07627	1.13559	1.22881	1.35297	1.55085	1.83898	2.27966	2.79661	Clear
(Partly Cloudy) 6	1.00000	1.12000	1.20000	1.36000	1.48000	1.72000	2.00000	2.40000	2.92000	3.56000	5 (Ocean)
7*	1.00000	1.03756	1.07981	1.13146	1.19249	1.29108	1.41315	1.59624	1.77465	2.01174	6 (Land/Desert)++ Partly Cloudy
8*	1.00000	1.03756	1.07981	1.13146	1.19249	1.29108	1.41315	1.59624	1.77465	2.01174	
9*	1.00000	1.03756	1.07981	1.13146	1.19249	1.29108	1.41315	1.59624	1.77465	2.01174	
10+	1.00000	1.06805	1.12426	1.21598	1.29882	1.44970	1.63018	1.89349	2.19822	2.58432	
(Mostly Cloudy) 11	1.00000	1.07843	1.13725	1.23529	1.29412	1.43137	1.56863	1.75686	1.96078	2.19608	7 (Ocean)
12*	1.00000	1.04700	1.10300	1.17000	1.24400	1.33200	1.42800	1.53400	1.65000	1.77500	8 (Land/Desert)++ Mostly Cloudy
13*	1.00000	1.04700	1.10300	1.17000	1.24400	1.33200	1.42800	1.53400	1.65000	1.77500	
14*	1.00000	1.04700	1.10300	1.17000	1.24400	1.33200	1.42800	1.53400	1.65000	1.77500	
15*	1.00000	1.08468	1.16216	1.25586	1.35135	1.46613	1.61171	1.77658	1.94685	2.14775	
(Overcast)16	1.00000	1.02353	1.07059	1.12941	1.17647	1.24706	1.31765	1.38824	1.45882	1.51765	9 Overcast

Directional Model Index Selection for Scanner Measurements

Geotype(G) = 1 (Ocean) and f_i = 1 (Clear) Then if f_i = 1, INDEX = G
Geotype(G) = 2 (Land) and f_i = 2 (Partly cloudy) Then if f_i = 2, INDEX = G + 5
Geotype(G) = 3 (Snow) and f_i = 3(Mostly cloudy) Then if f_i = 3, INDEX = G + 10
Geotype(G) = 4 (Desert) and f_i = 4 (Overcast) Then if f_i = 4, INDEX = 16
Geotype(G) = 5 (Land/Ocean)+

** Storing separate but identical models for land, snow, desert, and land/desert mix makes easier the generation of a scanner model index from cloud and geotype information.*
+ These are linear composite models (50-50 for each constituent), not independent models, which function as separate scene tyeps for scanner processing.
++ Snow geotypes must be either clear or overcast.

6. ERBE Directional Albedo Models (See Table 13)

Table 13: ERBE Directional Albedo Models

Model No.	Solar Zenith Angle Bin Number									
	1	2	3	4	5	6	7	8	9	10
1	.0760	.0820	.0910	.1010	.150	.1330	.1610	.2030	.2680	.3340
2	.1600	.1565	.1630	.1670	.1750	.1863	.2050	.2310	.2700	.3260
3	.6673	.6703	.6733	.6759	.6779	.6789	.6774	.6708	.6502	.6189
4	.2369	.2388	.2411	.2437	.2471	.2517	.2581	.2683	.2864	.3098
5	.1180	.1193	.1270	.1340	.1450	.1597	.1830	.2170	.2690	.3300
6	.1250	.1400	.1500	.1700	.1850	.2150	.2500	.3000	.3650	.4450
7	.2130	.2210	.2300	.2410	.2540	.2750	.3010	.3400	.3780	.4285
8	.1690	.1805	.1900	.2055	.2195	.2450	.2755	.3200	.3715	.4368
9	.2550	.2750	.2900	.3150	.3300	.3650	.4000	.4480	.5000	.5600
10	.3000	.3270	.3550	.3820	.4200	.4487	.4945	.5380	.5805	.6320
11	.2775	.3010	.3225	.3485	.3750	.4069	.4473	.4930	.5403	.5960
12	.4250	.4350	.4550	.4800	.5000	.5300	.5600	.5900	.6200	.6450

7. ERBE Scene Types (See Table 14)

Table 14: ERBE Scene Types

Model No.	Scene	Cloud Cover (Percent)
1	Ocean	0 < C < 5
2	Land	0 < C < 5
3	Snow	0 < C < 5
4	Desert	0 < C < 5
5	Mixed, Land-Ocean	0 < C < 5
6	Partly cloudy over ocean	5 < C < 50
7	Partly cloudy over land or desert	5 < C < 50
8	Partly cloudy over land-ocean mix	5 < C < 50
9	Mostly cloudy over ocean	50 < C < 95
10	Mostly cloudy over land or desert	50 < C < 95
11	Mostly cloudy over land-ocean mix	50 < C < 95
12	Overcast	95 < C < 100

8. ERBE Albedo Directional Models for Ocean Scenes.

9. ERBE Albedo Directional Models for Land Scenes.

10. ERBE Albedo Directional Models for Clear Over Snow and Clear Over Desert Scenes.

11. Half-sine Model for Nonscanner Longwave Flux

In nonscanner data, in some land regions like deserts and arid mountains, longwave flux exhibits a pronounced diurnal variation. A single diurnal fit to the monthly ensemble of all longwave data points based on a half-sine curve has been added to the nonscanner algorithm. Rather than daily fits, a fit is performed on monthly hourly averages. Given this month of data, there are five criteria which are applied to determine whether or not a good fit can be obtained:

1. Must have at least 1 daytime measurement located more than 1 hour from the terminator
2. Must have at least 1 nighttime measurement
3. A least squares sinewave fit to the daytime data must have a positive amplitude
4. The peak value of the daytime fit must not exceed 400 Wm^{-2}
5. The length of the day must exceed 2 hours

If any of these criteria are not met, the fit will not be performed and the already calculated averages will be retained.

The daytime curve is a least squares sine fit weighted by the number of measurements at each local hour. The nighttime data are simply averaged and the constant value is used for all night hours. These monthly hourly values for day and night are then stored. The resulting averages of longwave are stored in the arrays formerly used for the Monthly Hourly Longwave Average. The Daily Longwave Average values are replaced with the Monthly Hourly Longwave average values over land and deserts, if a fit is made. These Daily

Longwave Average values over land are then used to calculate net radiation for the land regions. The algorithm and data products for other scene types are unchanged.

A flag to indicate whether the half-sine fit was used in a given region was added to the first data record for each region.

Calculated Variables:

Before the data are packed and written to the output file, albedos are calculated for monthly (day), monthly (hour), daily, and monthly hourly average quantities. The albedos are calculated on a regional, zonal, and global basis using the following equations:

For monthly (day):

for individual regions:

$$\text{albedo} = \frac{\overline{M}_{SW} \cdot 24 \cdot \text{NDAYS}}{\text{TSOLRD}} \quad (2)$$

for nested regions, zones, and the globe:

$$\text{albedo} = \frac{\sum_{\text{regions}} \overline{M}_{SW} \cdot 24 \cdot \text{NDAYS}}{\sum_{\text{regions}} \text{TSOLRD}} \quad (1)$$

where:

$\overline{M}_{SW}$ = Monthly mean shortwave flux based on daily calculations.
TSOLRD = Total of monthly integrated solar incidence for all days of the month (see Reference 2).
NDAYS = The total number of days in the month.

This equation involves the assumption, previously made in calculating monthly regional net flux, that the regional albedo, calculated with (in general) some missing days, is representative of the entire month. The assumption is necessary because each region will have (in general) its flux defined for a different number of days.

For monthly (hour):

for individual regions:

$$\text{albedo} = \frac{\overline{M}_{SW} \cdot 24 \cdot \text{NDAYS}}{\text{TSOLRH}} \quad (15)$$

for nested regions, zones, and the globe:

$$\text{albedo} = \frac{\sum_{\text{regions}} \overline{M}_{SW} \cdot 24 \cdot \text{NDAYS}}{\sum_{\text{regions}} \text{TSOLRH}} \quad (16)$$

where:

$\overline{M}_{SW}$ = Monthly mean shortwave flux based on monthly hourly calculations.
TSOLRH = Total of monthly integrated solar incidence for all days of the month.
NDAYS = The total number of days in the month.

For daily values (for each day):

for individual regions:

$$\text{albedo} = \frac{\overline{M}_{SW} \cdot 24}{\text{SOLARD}} \quad (17)$$

for nested regions, zones, and the globe:

$$\text{albedo} = \frac{\sum_{\text{regions}} \overline{M}_{SW} \cdot 24}{\sum_{\text{regions}} \text{SOLARD}} \quad (18)$$

where:

$\overline{M}_{SW}$ = Daily shortwave flux.

SOLARD = Daily integrated solar incidence.

Given the hourly average shortwave flux and integrated solar incidence for a day, the albedo is defined as the total reflected energy divided by the total incident energy.

For monthly hourly (for each hour of a given month):

for individual regions:

$$\text{albedo} = \frac{M_{SW} \cdot D_{SW}}{SOLARH} \quad (19)$$

for nested regions, zones, and the globe:

$$\text{albedo} = \frac{\sum_{regions} M_{SW} \cdot D_{SW}}{\sum_{regions} SOLARH} \quad (20)$$

where:
M_{SW}: = Daily shortwave radiant flux for each hour of the month.
SOLARH: = Integrated solar incidence for the month
D_{sw} = Days with at least one shortwave measurement including those days of total darkness where shortwave is defined as 0.

Graphs and Plots:

- Albedo.
- Clear Sky Albedo.
- Clear-Sky Longwave Radiation.
- Clear-Sky Net Radiation.
- Clear-Sky Shortwave Radiation.
- Longwave Radiation.
- Longwave Cloud Forcing.
- Net Radiation.
- Net Cloud Forcing.
- Shortwave Radiation.
- Shortwave Cloud Forcing.

10. Errors:

Sources of Error:

A discussion of various factors that may lead to errors are discussed in the Confidence Level/Accuracy Judgement Section of this document.

Quality Assessment:

Data Validation by Source:

The measurement of radiation budget requires a massive data processing system. ERBE's system uses about 250,000 lines of FORTRAN code. This system also uses an additional 150,000 lines of off-line diagnostic work. The stringent requirements for accuracy in the budget dictate an acute attention to detail.

The ERBE data processing system uses about 25,000 coefficients. These coefficients are conveniently arranged in three groups. The first group is the set of "calibration coefficients" that appear in the algorithms converting telemetry counts to instrument irradiation. Ground- and in-flight-calibration sources provided these coefficients. The second group includes the angular distribution models (ADMs) and spectral unfiltering coefficients needed for inversion. A categorization of the Nimbus-7 ERB measurements forms the base for the ADM's. Missing bins were filled using the reciprocity principle. A combination of radiative transfer results and measurements of the instrument spectral responses provides the spectral correction coefficients. The third and final group of parameters consists of the coefficients needed for time averaging, mainly the directional models. These models describe the dependence of each scene type's albedo upon solar zenithangle. These directional models also came from the Nimbus-7 ERB, but have been suitably supplemented by Geostationary Operational Environmental Satellite (GOES) observations where needed. The majority of the coefficients are used in the inversion process.

The earth's radiation budget is not easy to measure, even indirectly. The ERBE Science Team has relied on consistency and measurement intercomparisons for validation. Fortunately, ERBE data provides a number of these checks. These criteria provide a way of judging the consistency of the various parameters in the data processing system.

Confidence Level/Accuracy Judgement:

The ERBE data products are complex assemblages of data and models. Thus, their uncertainties are difficult to compute. The following numbers represent estimates of the standard deviations about a given data point within which the true measurement might lie. They are not definitive confidence intervals, but are intuitively based on the observed discrepancies in the intercomparisons. It is also important to remember that different measurements have different uncertainties. First, for instantaneous radiances, we expect uncertainties of about 10f longwave observations of filtered radiance and 2 0.000000 or shortwave. Radiative transfer comparison and spectral consistency provide the basis for this uncertainty estimate. Second, on an instantaneous observation of flux from 2.5 X 2.5 degree geographic regions, the ERBS/NOAA-9 intercomparisons offer reasonable estimates of uncertainty. These are 5 Wm^{-2} in the longwave and 15 Wm^{-2} in the shortwave. Third, on a monthly average, regional basis, the uncertainties in the scanner data are about 5 Wm^{-2} for shortwave and 5 Wm^{-2} for longwave. These come from simulations with GOES data. This uncertainty represents no change from the preflight estimate. The nonscanner averages may be somewhat more uncertain because of sampling and diurnal averaging process. Fourth, the uncertainty in global, annual average net radiation is probably about 5 Wm^{-2}. This estimate is based on the imbalance obtained using scanner data from the four validation months (April, July, and October 1985; January 1986).

Measurement Error for Parameters:

Measurement errors are mentioned in the Confidence Level/Accuracy Judgement Section of this document.

Additional Quality Assessments:

None.

Data Verification by Data Center:

The data were transferred to the ASDC via ftp. Before the data were archived, the ASDC checked all granules to ensure that the size of the granules matched that what was delivered on the media. The version number of the granules were also checked so that the most current version of the data are available to the user community. Granule level metadata were extracted from the granules such as the product ID, satellite(s) ID, and data date.

11. Notes:

Limitations of the Data:

There are no know limitations or unreliable aspects in the algorithms implemented to generate the ERBE science data.

Known Problems with the Data:

There are no known problems or inconsistencies in the ERBE data.

Usage Guidance:

The monthly hourly averaged results are a combination of measurements and models. The mean of these results represents the best estimate of the monthly hourly results. Also note that one should not just average the measurements alone to determine the monthly hourly means, because it will give a misleading diurnal cycle. The combination of measurements and models gives a more reasonable estimate when compared to full-time sampling of the GOES.

Any Other Relevant Information about the Study:

None.

12. Application of the Data Set:

Measurements of the radiation budget provide one of the important tools for the validation of numerical models of the atmosphere. They also provide possibilities for "climate experiments" by allowing the sensitivity of the radiation budget to various forcings to be studied empirically.

The use of cloud discrimination has provided a significant new source of information on the influence of clouds and the characteristics of clear-sky fluxes. This information is particularly important in understanding cloud forcing. It is also important in describing the response of clouds to climate change: the climate cloud sensitivity.

13. Future Modifications and Plans:

The ERBE project plans to complete the reprocessing, which is currently in progress, of the nonscanner data using inversion and time/space averaging processes which do not use scanner scene identification information.

Current plans are to reprocess the ERBE scanner data beginning in 1996 using the CERES algorithms.

To continue the measurements of the radiation budget, a second project,the Clouds and the Earth's Radiant Energy System (CERES), is currently being developed. CERES is a key component of the Earth Observing System (EOS). The CERES instruments are improved models of the Earth Radiation Budget Experiment (ERBE) scanner instruments. The strategy of flying instruments on Sun-synchronous, polar orbiting satellites, such as NOAA-9 and NOAA-10, simultaneously with instruments on satellites that have precessing orbits in lower inclinations, such as ERBS, was successfully developed in ERBE to reduce time sampling errors. CERES will continue that strategy by flying instruments on the polar orbiting EOS platforms simultaneously with an instrument on the Tropical Rainfall Measuring Mission (TRMM) spacecraft, which has an orbital inclination of 35 degrees. In addition, to reduce the uncertainty in data interpretation and to improve the consistency between the cloud parameters and the radiation fields, CERES will include cloud imager data and other atmospheric parameters. The first CERES instrument is scheduled to be launched on the TRMM spacecraft in 1997. Additional CERES instruments will fly on the EOS-AM platforms, the first of which is scheduled for launch in 1998, and on the EOS-PM platforms, the first of which is scheduled for launch in 2000.

14. Software:

Software Description:

There are two programs available from the EOSDIS Langley ASDC which read the S-4G HDF files. One program reads the scanner data files while the other reads the nonscanner data files. Each of these programs is available in both C and FORTRAN 77.

These programs allow the user to read data and associated metadata to an ASCII file for a given data month, year, and satellite coverage. The programs allow you to select the type of average (regional, zonal, or global); the resolution (2.5-, 5.0-, or 10.0-degrees as applicable to the data); and, for the nonscanner data, the field-of-view (medium or wide) and either numerical filter or shape factor. These selections will restrict the data to one of the 14 S-4G HDF files. You can further subset the data selection by choosing a geographic region to read. This can be done by selecting a range of regions based on the equal-angle grid or by selecting latitude and longitude ranges. A menu of available parameters allows for the selection of particular data measurements (e.g., Longwave, Shortwave, etc.).

In order to run the read software, you will need to obtain the HDF libraries which are available in the public domain from the National Center for Supercomputing Applications (NCSA) via ftp (ftp.ncsa.uiuc.edu or 128.174.20.50). These programs, along with a sample session, can be obtained through the Langley ASDC Information Management System interface or by contacting:

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Comments or questions on the read software should also be sent to the Langley ASDC User and Data Services.

Software Access:

Typically, LaRC ASDC User Services will fill the data order and include any and all data manipulation software related to the data in the order. However, in order to compile and execute the HDF read software, you will need to obtain the HDF libraries. These libraries are in the public domain and are available from the National Center for Supercomputing Applications (NCSA) via ftp (ftp.ncsa.uiuc.edu or 128.174.20.50).

15. Data Access:

Contact Information:

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656

FAX: (757) 864-8807
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FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Procedures for Obtaining Data:

Data, programs for reading the data, and user's guides can be obtained through the EOSDIS Langley ASDC on-line system which will allow users to search through the data inventory and place orders on-line.

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov
URL: http://eosweb.larc.nasa.gov

The Langley ASDC User and Data Services staff provides technical and operational support for users ordering data.

Data Center Status/Plans:

On a regular basis, individual ERBE data granules are reviewed by local members of the ERBE Science Team. Upon Science Team approval, the ERBE Data Management Team releases the data granule to the LaRC ASDC for archive.

16. Output Products and Availability:

There are no ERBE S-4G output products available other than the data granules.

17. References:

1. Brooks, D. R., E. F. Harrison, P. Minnis, J. T. Suttles, and R. S. Kandel, "Development of Algorithms for Understanding the Temporal and Spatial Variability of the Earth's Radiation Balance," *Reviews of Geophysics and Space Physics*, 24, 422-438, 1986.

2. Brooks, D. R., and P. Minnis, "Comparison of Longwave Diurnal Models Applied to Simulations of the Earth Radiation Budget Experiment," *Journal of Climate and Applied Meteorology*, 23, 155-160, 1984.

3. *Earth Data Management System Reference Manual, Volume VI, Daily Data Base and Monthly Time/Space Averaging*, November 1986.

4. *Earth Radiant Fluxes and Albedo, Scanner S-9, Nonscanner S-10/S-10N User's Guide, Revision 1*, March 1993.

5. *ERBE Data Management System Reference Manual, Volumes Va and Vb, Inversion*, August 1987.

6. *ERBE Data Management System Reference Manual, Volume VII, Output Products*, September 1986.

7. Kopia, L. P., "The Earth Radiation Budget Experiment Scanning Instrument," *Reviews of Geophysics and Space Physics*, 24, 400-406, 1986.

8. Luther, M. R., J. E. Cooper, and G. RT. Taylor, "The Earth Radiation Budget Experiment Nonscanning Instrument," *Reviews of Geophysics and Space Physics*, 24, 391-399, 1986.

9. *Monthly Medium-Wide Data Tape S-7 User's Guide, Revision 1*, February 1993.

10. *Processed Archival Tape S-8 PAT User's Guide*, December 1987.

11. *Raw Archival Tape S-1 User's Guide*, July 1985.

12. *The Regional, Zonal, and Global averages, S-4/S-4N User's Guide, Revision 1,* June 1993.

13. Smith, G. L., R. N. Green, E. Raschke, L. M. Avis, B. A. Wielicki, and R. Davies. "Inversion Methods for Satellite Studies of the Earth's Radiation Budget: Development of Algorithms for the ERBE Missions." *Rev. of Geophys.*, 24:407-421, 1986.

14. Sorlie, S. *Langley DAAC Handbook.* NASA Langley Research Center, Hampton, Virginia, February 1993.

18. Glossary of Terms:

EOSDIS Glossary.

Albedo
: The ratio of shortwave radiant flux to the integrated solar incidence, where zero (0.0) represents total absorption, and one (1.0) represents total reflectance.

Level 2
: Level 2 is a data product level referring to retrieved environmental variables (e.g., ocean wave height, soil moisture, ice concentration).

Nadir
: That point on the celestial sphere vertically below the observer, or 180 degree from the zenith.

Radiance
: The radiant flux per unit solid angle per unit of projected area of the source; usual unit is the watt per square meter per steradian. Also known as steradiancy.

Radiant Flux
: The time rate of flow of radiant energy.

S-4: Regional, Zonal, and Global Averages Product
: The S-4 contains averages of flux and albedo on regional, zonal, and global scales for both scanner and nonscanner data. For more information on this product please refer to the ERBE S-4 Data Set Document.

S-4N: Regional, Zonal, and Global Averages Product
: The S-4N contains averages of flux and albedo on regional, zonal, and global scales for both scanner and nonscanner data. For more information on this product please refer to the ERBE S-4N Data Set Document.

S-4G: Regional, Zonal, and Global Gridded Averages Product
: The S-4G contains averages of flux and albedo on regional, zonal, and global scales for both scanner and nonscanner data. The S-4G product is arranged by parameter value.

S-4GN: Regional, Zonal, and Global Gridded Averages Product
: The S-4GN contains averages of flux and albedo on regional, zonal, and global scales for nonscanner data. The S-4GN product is arranged by parameter value. For more information on this product please refer to the ERBE S-4GN Data Set Document.

S-7: Medium-Wide Field-of-View Data Tape
: The S-7 product contains a condensed version of the nonscanner data that are found in a monthly set of the S-8 product, **except** that the shortwave estimates of the radiant flux at the top-of-atmosphere (TOA) are based on the mostly-cloudy over ocean bidirectional model. The S-7 product then provides a consistent data set of nonscanner TOA estimates which are not dependent on scene type and, therefore, not dependent on the operational status of the ERBE scanner instruments.

S-8: Processed Archival Tape
: The S-8 contains ERBE scanner and nonscanner radiometric measurements for one day and one satellite. Estimates of the flux at the TOA based on these measurements are also included.

S-9: Earth Radiant Fluxes and Albedo for Month (Scanner)
: The S-9 contains regional hourly and daily monthly averages as well as the actual individual hour box data which is the input data to the Monthly Time/Space Averaging Subsystem. The S-9 contains 2.5-degree resolution data from the scanner instrument. For more information on this product please refer to the ERBE S-9/S-10 Data Set Document.

S-10: Earth Radiant Fluxes and Albedo for Month (Nonscanner)
: The S-10 contains regional hourly and daily monthly averages as well as the actual individual hour box data which are the input data to the Monthly Time/Space Averaging Subsystem. The S-10 contains numerical filter data of 5-degree resolution and shape factor data of 10-degree resolution from the nonscanner instrument. For more information on this product please refer to the ERBE S-9/S-10 Data Set Document.

S-10N: Earth Radiant Fluxes and Albedo for Month (Nonscanner)
: The S-10N product contains the same science information arranged in the same order as the S-10; however, there are some differences in the processing algorithms and data format. The data set S-10N consists of nonscanner data processed without scene identification from the scanner and with numerical filter cross-track enhancement technique. For more information on this product please refer to the ERBE S-10N Data Set Document.

TSI: Total Solar Irradiance from the ERBS Satellite
: The TSI product contains total solar irradiance data that were collected every two weeks from the solar monitor. Each granule consists of six months of data and is in ASCII format.

Solar Incidence

Total energy per unit area impinging on the earth from the sun.

Zenith

That point on the celestial sphere vertically above the observer.

19. List of Acronyms:

EOSDIS Acronyms.

ADM - Angular Distribution Model
AVHRR - Advanced Very High Resolution Radiometer
ASCII - American Standard Code for Information Interchange
CERES - Clouds and Earth's Radiant Energy System
DAAC - Distributed Active Archive Center
DBMS - Database Management System
EOSDIS - Earth Observing System Data and Information System
ERB - Earth Radiation Budget
ERBE - Earth Radiation Budget Experiment
ERBS - Earth Radiation Budget Satellite
FOV - Field-of-View
GOES - Geostationary Operational Environmental Satellite
GSFC - Goddard Space Flight Center
HDF - Hierarchical Data Format
HIRS - High-Resolution Infrared Radiometer Sounder
IBB - Internal Blackbody
IPTS-68 - International Pressure and Temperature Standard of 1968
IMS - Information Management System
LaRC - Langley Research Center
LW - Longwave
LWF - Longwave Flux
MFOV - Medium Field-of-View
MRBB - Master reference blackbody
NASA - National Aeronautics and Space Administration
NCSA - National Center for Supercomputing Applications
NESDIS - National Environmental Satellite Data and Information Service
NFOV - Narrow Field-of-View
NOAA - National Oceanic and Atmospheric Administration
NOAA-9 - National Oceanic and Atmospheric Administration Operational Weather Monitoring Satellite number 9
NOAA-10 - National Oceanic and Atmospheric Administration Operational Weather Monitoring Satellite number 10
NORAD - North American Aerospace Defense Command
POCC - Payload Operation and Control Center
SAGE II - Stratospheric Aerosol and Gas Experiment II
SOCC - Satellite Operations and Control Center (NOAA)
SW - Shortwave
SWF - Shortwave Flux
SWICS - Shortwave Internal Calibration Source
TDRSS - Tracking and Data Relay Satellite System
TIROS - Television Infrared Radiometer Orbiting Satellite
TOA--Top-of-Atmosphere
TOT - Total (as in total channel)
URL - Uniform Resource Locator
UT - Universal Time
WFOV - Wide Field-of-View
WRR - World Radiation Reference

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