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

Data Management System

Software Requirements Document

Synoptic Surface and Atmospheric Radiation Budget
(Subsystem 7.2)

Release 1
Version 1

Lisa H. Coleman

Lockheed Engineering & Sciences Company (LESC)
144 Research Drive
Hampton, VA 23666

Atmospheric Sciences Division
NASA Langley Research Center
Hampton, Virginia 23681-0001

March 1995

Preface

The Clouds and the Earth's Radiant Energy System (CERES) Data Management System supports the data processing needs of the CERES Science Team research to increase understanding of the Earth's climate and radiant environment. The CERES Data Management Team works with the CERES Science Team to develop the software necessary to support the science algorithms. This software, being developed to operate at the Langley Distributed Active Archive Center, produces an extensive set of science data products.

The Data Management System consists of 12 subsystems; each subsystem represents a stand-alone executable program. Each subsystem executes when all of its required input data sets are available and produces one or more archival science products.

The documentation for each subsystem describes the software design at various significant milestones and includes items such as Software Requirements Documents, Data Products Catalogs, Software Design Documents, Software Test Plans, and User's Guides.

TABLE OF CONTENTS

List of Figures

List of Tables

1.0 Introduction

The Clouds and the Earth's Radiant Energy System (CERES) program is a key component of the Earth Observing System (EOS). The CERES instrument will provide radiometric measurements of the Earth's atmosphere from three broadband channels: a shortwave channel (0.2 - 5.0µm), a total channel (0.2 - 50µm), and an infrared window channel (8-12µm). The CERES instrument is an improved model of the Earth Radiation Budget Experiment (ERBE) scanner, which was first flown aboard the Earth Radiation Budget Satellite (ERBS) from November 1984 until February 1990 in a 57-deg inclination orbit. During much of the same time period, additional ERBE scanner instruments flew on the National Oceanic and Atmospheric Administration (NOAA) Sun-synchronous, polar orbiting satellites NOAA-9 and NOAA-10. To reduce temporal sampling errors, ERBE successfully developed the strategy of flying instruments on Sun-synchronous, polar orbiting satellites with instruments on satellites with lower inclination orbits. Following the same strategy, the first CERES instrument is expected to be launched in 1997 aboard the Tropical Rainfall Measuring Mission (TRMM), a satellite with an orbital inclination of 35 degrees. Additional CERES instruments will be flown aboard the polar orbiting EOS-AM and EOS-PM platforms. The first EOS-AM platform is expected to be launched in 1998, while the first EOS-PM platform is expected to be launched in 2000. As an improvement to the ERBE strategy, CERES will include cloud imager data and other atmospheric parameters in order to increase the certainty of the data and improve the consistency between the cloud parameters and the radiation fields.

The CERES Synoptic Surface and Atmospheric Radiation Budget (SARB) Subsystem software will compute the vertical atmospheric profiles of shortwave (SW) and longwave (LW) radiative fluxes over 1.25-deg equal area regions included in a global, 3-hourly, synoptic map. The vertical profile will extend from the surface to the top-of-the-atmosphere (TOA). Prior to execution of the Synoptic SARB Subsystem, several other steps that result in the synoptic map must be executed. First, CERES data is processed on a footprint-level, a footprint being the area viewed on the Earth for an individual CERES scanner measurement. One-hour segments of footprint data from a single satellite are processed at a time. For each CERES footprint, cloud properties are determined and TOA fluxes derived. These data are archived on the Single Satellite Flux (SSF) product. Given the footprint-level cloud properties and TOA fluxes, the Footprint SARB Subsystem computes the vertical atmospheric profiles of shortwave and longwave radiative fluxes for each footprint by applying radiative transfer techniques. These data are stored on the Cloud and Radiation Swath (CRS) product. Next, the footprint-level cloud properties, TOA fluxes, and vertical atmospheric flux profiles are averaged over 1.25-deg equal area regions and archived on the Flux and Clouds Regional Swath (FSW) product. Then, the single satellite, hourly averages of CERES cloud properties and TOA fluxes are merged with hourly averaged CERES data from other concurrent satellites. These cloud properties and TOA fluxes are then interpolated to produce the 3-hourly, global, synoptic maps. Given the synoptic cloud properties and TOA fluxes, the Synoptic SARB Subsystem applies the same radiative transfer techniques to regional data that the Footprint SARB Subsystem applied to footprint-level data. The same tuning process implemented by the Footprint SARB Subsystem will also be implemented by the Synoptic SARB Subsystem. The techniques used by both of these subsystems are discussed in References 1 and

2. The synoptic cloud properties, TOA fluxes, and vertical atmospheric flux profiles are archived on the Synoptic (SYN) product.

The Synoptic SARB Subsystem is actually the second half of a larger subsystem, the Merge Satellites, Time Interpolate, and Compute Fluxes Subsystem, which is number 7.0 in the CERES subsystem numbering scheme. The first half of Subsystem 7.0 is the Time Interpolation for Single and Multiple Satellites Subsystem. To distinguish between the two, the first half is numbered as 7.1, and the Synoptic SARB half is numbered as 7.2. The Time Interpolation for Single and Multiple Satellites Subsystem produces the temporary, nonarchival Time Space Interpolate (TSI) product that the Synoptic SARB Subsystem requires as input.

Once subsystem processing for the Synoptic SARB Subsystem has been initialized, data from the TSI file will be ingested one region at a time, and then the vertical atmospheric flux profiles will be calculated and written to the SYN. To calculate this vertical atmospheric flux profile, ancillary data from the Meteorological, Ozone, and Aerosol (MOA), the Surface Map Properties (SURFMAP), and the Surface Radiative Properties Climatology (SRC) input files will also be used. The tuning process will require additional input from the empirically precomputed Derivative Tables (DRIVTAB) product. Once data for all of the TSI regions have been processed, the Synoptic SARB Subsystem will generate the Quality Control Report for Synoptic SARB (QCSS) and perform the necessary finalization procedures. The TSI and other input products required for subsystem processing, along with the output products generated, are discussed in SectionSection 2.0.

The CERES software will be developed in three incremental releases. The first two releases will be completed prior to the launch of the TRMM satellite, while the third release is planned for about 18 months after the TRMM launch. With each release, the associated documentation will be updated. This document is intended to specify the requirements of the Synoptic SARB Subsystem software that the CERES Data Management Team (DMT) is responsible for developing for Release 1. Based on these requirements, both the Release 1 software design and test procedures for this Subsystem will be written.

As already noted, the Synoptic SARB Subsystem will apply the same techniques for calculating and tuning the vertical profile of the shortwave and longwave radiative fluxes that the Footprint SARB Subsystem applies. For this reason, much of the same software will be used by both subsystems. The operating modes, functional requirements, design goals, and resource use discussed in the Software Requirements Document for the Footprint SARB Subsystem (Reference 3) are also applicable to the Synoptic SARB Subsystem and will not be repeated in this document. Differences between the two subsystems will be driven by different file structures of the primary input and output products. Minor differences will also be noticed in the quality control reports and metadata files, for which the contents are still to be determined (TBD).

The overall approach taken to gather the requirements stated in this document include the use of the Algorithm Theoretical Basis Document (ATBD) for the Synoptic SARB Subsystem

(Reference 1), information gleaned from attending meetings of the SARB Working Group, and from collaboration with members of this group and other members of the CERES DMT.

2.0 External Interface Requirements

A context diagram indicating the input and output requirements of the Synoptic SARB Subsystem is shown in Figure 2-1. Input data required by this Subsystem include the temporally varying TSI, MOA, and SURFMAP products, along with data defined prior to processing, such as the Processing and Control Parameters for Synoptic SARB (PCPSS), DRIVTAB, and SRC products. The primary output from this Subsystem is the SYN product. Also required to be output is the QCSS report that displays run-time statistics, and the EOSDIS-required file of Metadata for the Synoptic SARB (METASS).

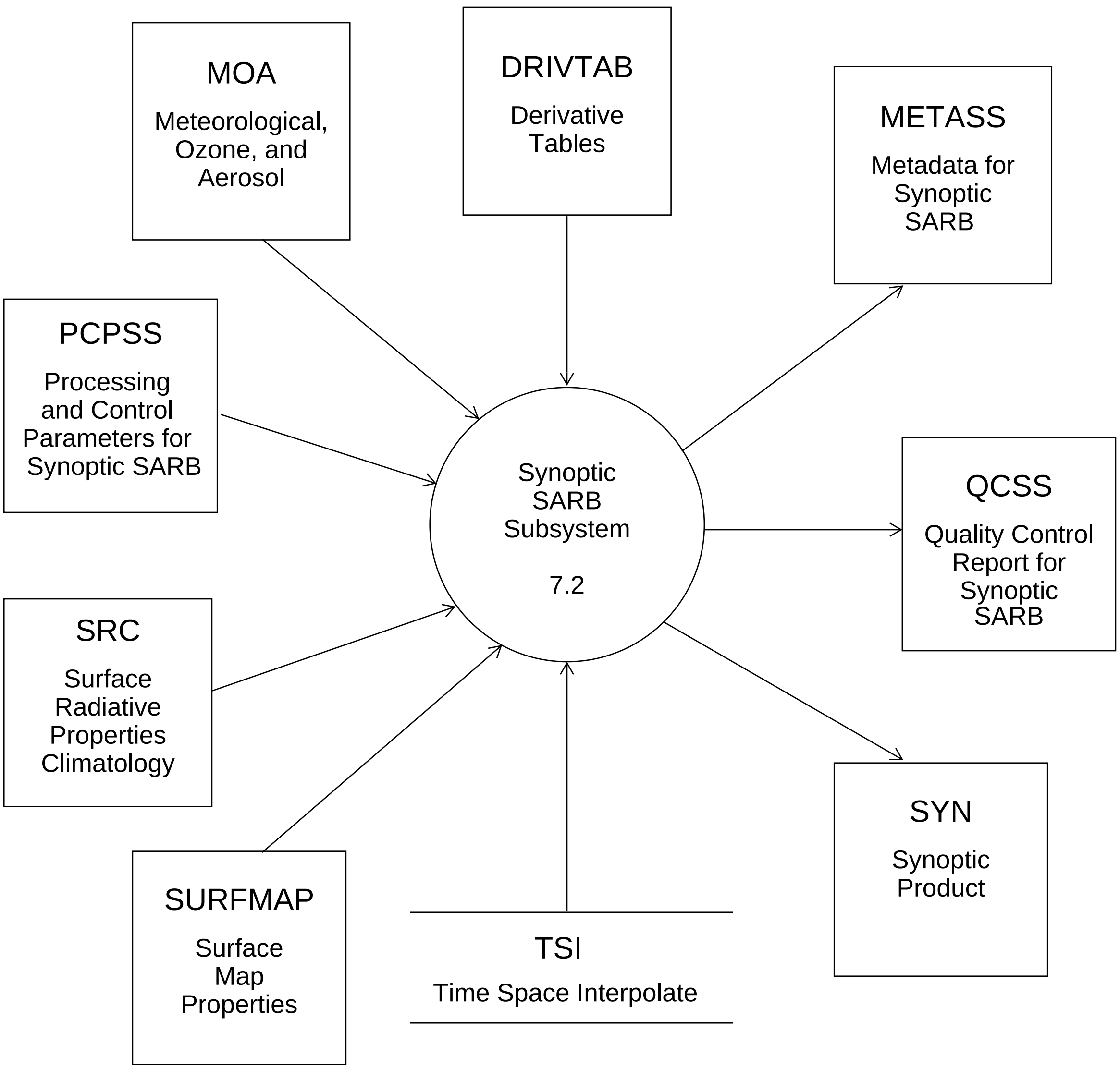

Figure 2-1. Context Diagram

2.1 Input Products

2.1.1 Derivative Tables (DRIVTAB)

The DRIVTAB product will contain precomputed tables consisting of the finite difference approximations of the derivatives required by the SARB tuning process. The derivatives are the change in TOA fluxes with respect to a small change in a selected tuning parameter, while other input parameters remain fixed. DRIVTAB will contain derivatives of TOA with respect to several different tuning parameters.

For the shortwave portion of the atmospheric flux profiles there will be derivatives based on changes to the surface albedo (dTOA/dALB), aerosol optical depth (dTOA/dAER), and cloud optical depth (dTOA/dTAU). These values will be computed and supplied by the SARB Working Group.

Currently, calculations of the shortwave derivatives are based on the following:

dTOA/dALB : 50 precipitable water values, 20 solar zenith angles, and 21 surface albedo values divided into 20 integrals (total of 20,000 derivatives).

dTOA/dAER : 31 precipitable water values, 20 solar zenith angles, 13 surface albedo values, and 15 aerosol optical depth values divided into 14 integrals (total of 112,840 derivatives).

dTOA/dTAU : 14 precipitable water values, 10 solar zenith angles, 10 surface albedo values, 14 cloud heights, and 31 cloud optical depth values divided into 30 integrals (total of 588,000 derivatives).

Definition of the derivatives required for tuning the longwave portion of the atmospheric flux profiles is not yet complete. However, the parameters that will contribute to the longwave derivatives include precipitable water, cloud height, cloud optical depth, and the surface temperature.

2.1.2 Meteorological, Ozone, and Aerosol (MOA)

The MOA, a CERES archival product, is produced by the CERES Regrid Humidity and Temperature Subsystem. Each MOA file contains meteorological, ozone, and aerosol data for one hour, and is used by several of the CERES subsystems. Data on the MOA are derived from several data sources external to the CERES system, such as National Meteorological Center (NMC), Moderate Resolution Imaging Spectrometer (MODIS), the Stratospheric Aerosol and Gas Experiment (SAGE), and various other sources. These data arrive anywhere from four times daily to once a month and are horizontally and vertically organized differently from what the CERES system requires. The Regrid Humidity and Temperature Subsystem interpolates these data temporally, horizontally, and vertically to conform with CERES processing requirements. A detailed list of the parameters included on the MOA product is given in Reference 2.

Prior to an EOS-wide review of each project's ATBDs in May 1994, the MOA was referred to as the Atmospheric Structures (ASTR) file. At the request of the review panel, the name of this file was changed so as to avoid confusion with another EOS project, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER).

The MOA contains:

- Surface temperature and pressure.
- Vertical profiles of temperature, humidity, and geopotential height as a function of pressure for the internal atmospheric levels requested by the Clouds and SARB Working Groups.
- Column precipitable water.
- Vertical ozone profiles for internal atmospheric levels requested by the SARB Working Group.
- Column ozone.
- Total column aerosol.
- Stratospheric aerosol.

The internal atmospheric levels, in hPa, as requested by the CERES Clouds and SARB Working Groups as of December 1993, are listed in Table 2-1. It should be noted that prior to Release 2, the number of levels most likely will change from 38, and the levels themselves may also change.

Table 2-1. MOA Internal Atmospheric Levels (in hPa)

Floating Levels	**1000 to 875**	**850 to 725**	**700 to 450**	**400 to 225**	**200 to 70**	**50 to 1**
Surface	1000	850	700	400	200	50
Surface - 10	975	825	650	350	175	30
Surface - 20	950	800	600	300	150	10
	925	775	550	275	125	5
	900	750	500	250	100	1
	875	725	450	225	70	

2.1.3 Processing and Control Parameters for Synoptic SARB (PCPSS)

Processing and control parameters used by the Synoptic SARB Subsystem, contained in the PCPSS product, are defined prior to subsystem processing and ingested by the Subsystem at run-time. Potential processing and control parameters known at this time for this Subsystem are listed in Table 2-2. This list will be expanded as designing and actual coding take place. The SARB Working Group, along with other members of the CERES Science Team, will supply the values of these parameters.

Table 2-2. Known Processing and Control Parameters

Parameter Description
Maximum number of tuning iterations
Maximum longwave flux difference to be considered a match (percentage)
Maximum shortwave flux difference to be considered a match (percentage)
QC tuning sigmas for adjustment parameters, such as the expected error for input sounding of precipitable water, and the expected error for input sounding of surface skin temperature over sea and land (note that some of these values may be dependent on scene type)
Number of atmospheric levels in vertical profile for which to calculate synoptic longwave and shortwave fluxes
Pressure of fixed atmospheric levels in vertical profile for which to calculate longwave and shortwave synoptic fluxes
Number of atmospheric levels in vertical profile for which longwave and shortwave synoptic fluxes are archived
Pressure of fixed atmospheric levels in vertical profile for which longwave and shortwave synoptic fluxes are archived
Maximum difference (in hPa) between a cloud top (or bottom) level and a fixed atmospheric level that warrants the use of the cloud top (or bottom) level in the vertical profile instead of the fixed atmospheric level

2.1.4 Surface Radiative Properties Climatology (SRC)

The definition of the contents of the SRC file, and consequently its structure, is still under development by the SARB Working Group. For the different surface types identified in the SURFMAP data file, the SRC will contain radiative properties, such as albedo, infrared emissivity, and bidirectional reflectance.

2.1.5 Surface Map Properties (SURFMAP)

The SURFMAP will consist of multiple files denoting various characteristics of the Earth's surface. These characteristics will be arranged on an equal-area grid of the finest resolution possible. The characteristics to be included on the SURFMAP include:

- Broadband shortwave surface Angular Distribution Model (ADM) type.
- Digital elevation map.
- Ice map.
- Snow map.
- Spectral emissivity from 3.7μm channel imager data.
- Spectral emissivity from 11.0μm channel imager data.
- Surface type indicator.
- Vegetation map.
- Visible albedo for collimated, overhead Sun illumination.
- Water map.

A detailed list of the parameters included on the SURFMAP product is given in Reference 4.

2.1.6 Time Space Interpolate Product (TSI)

The TSI product contains a global, 3-hourly synoptic map of TOA fluxes and cloud conditions. It is produced by interpolating regional data to the fixed Universal Times of 0, 3, 6,...,21 GMT for each day of the month for each 1.25-deg region of the globe. There will be one TSI product produced for each satellite and one TSI product produced for each combination of satellites flying concurrently with CERES instruments on board. The maximum number of TSI products produced will be eight per spacecraft or combination of spacecraft per day. A summary of parameters contained on the TSI can be found in Reference 5

2.2 Output Products

2.2.1 Synoptic Product (SYN)

The SYN, a CERES archival product, is produced by the Synoptic SARB Subsystem. Each SYN file contains regional longwave (LW) and shortwave (SW) radiative fluxes for the surface, internal atmosphere and TOA. The data are computed at 3-hour synoptic intervals on a 1.25-deg equal area grid, and are based on measurements from multiple EOS CERES instruments. A detailed list of the parameters included on the SYN product is given in Reference 4.

The SYN contains global maps, at regular synoptic intervals, of:

- Regional data, such as region number and land and sea area percentages.
- Observed CERES TOA data for clear-sky and total-sky.
- Cloud category properties for four (low, lower middle, upper middle and high) cloud layers.
- Column-averaged cloud properties for five (TOA SW, TOA LW, Surface LW, Liquid Water Content, and Ice Water Content) weighting schemes.
- Overlap data for eleven (clear, low (L), lower middle (LM), upper middle (UM), high (H), H/UM, H/LM, H/L, UM/LM, UM/L, LM/L) cloud overlap conditions.
- Angular model scene classes for the ERBE scene types.
- Atmospheric flux profile for both clear-sky and total-sky at the surface, 500hPa, the tropopause and the TOA.
- Flux adjustments (tuned-untuned) for clear-sky and total-sky at the surface and TOA.
- Surface-only data.
- Adjustment parameters for clear skies.
- Adjustment parameters for L, LM, UM, and H cloud layers.

2.2.2 Metadata for Synoptic SARB (METASS)

The contents of the METASS product, a requirement of EOSDIS, are TBD.

2.2.3 Quality Control Report for Synoptic SARB (QCSS)

The QCSS product will contain statistics accumulated during processing of the Synoptic SARB Subsystem. The purpose of this product is to provide both Science Team and DMT members with a diagnostic report from which Subsystem processing results can be reviewed. These reports will be stored electronically and may be reviewed individually or with others as a tool to assist in the study of possible trends. While the exact contents of QCSS are still TBD, they may include such things as processing time, the number of occurrences of events such as out-of-range values and unsuccessful tuning attempts, shortwave and longwave flux averages according to colatitudinal bins, and scene-type sampling. As the design and coding take place, the SARB Working Group will indicate what values they would like to see displayed in this report.

References

1. Clouds and the Earth's Radiant Energy System (CERES) Algorithm Theoretical Basis Document, Time Interpolation and Synoptic Flux Computation for Single and Multiple Satellites (Subsystem 7.0), Release 1.1, Young, David F., Edwin F. Harrison, Bruce A. Wielicki, Patrick Minnis, Gary G. Gibson, Bruce R. Barkstrom, Thomas P. Charlock, David R. Doelling, Alvin J. Miller, Olivia C. Smith, Joseph C. Stassi, Atmospheric Sciences Division, NASA Langley Research Center, Hampton, VA, April 1994.

2. Clouds and the Earth's Radiant Energy System (CERES) Algorithm Theoretical Basis Document, Compute Surface and Atmospheric Fluxes (Subsystem 5.0), Charlock, T. P., G. L. Smith, T. D. Bess, D. Rutan, F. Rose, T. Alberta, N. Manalo-Smith, L. Coleman, D. Kratz, K. Bush, Atmospheric Sciences Division, NASA Langley Research Center, Hampton, VA, April 1994.

3. Clouds and the Earth's Radiant Energy System (CERES) Data Management System Footprint Surface and Atmospheric Radiation Budget (SARB) Subsystem (Subsystem 5) Software Requirements Document, Release 1, NASA Langley Research Center, Hampton, VA, November 1994.

4. Clouds and the Earth's Radiant Energy System Data Management System Data Products Catalog, Release 1 Version 1, Atmospheric Sciences Division, NASA Langley Research Center, Hampton, VA, August 1994.

5. Clouds and the Earth's Radiant Energy System (CERES) Data Management System Time Interpolation for Single and Multiple Satellites (Subsystem 7.1) Software Requirements Document, Release 1, NASA Langley Research Center, Hampton, VA, November 1994.

Abbreviations and Acronyms

ADM	Angular Distribution Model
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTR	Atmospheric Structures Product
ATBD	Algorithm Theoretical Basis Document
CERES	Clouds and the Earth's Radiant Energy System
CRS	Cloud and Radiation Swath Product
DMT	Data Management Team
DRIVTAB	Derivative Tables Product
dTOA/dAER	Derivative of change in TOA flux with respect to change in aerosol optical depth
dTOA/dALB	Derivative of change in TOA flux with respect to change in surface albedo
dTOA/dTAU	Derivative of change in TOA flux with respect to change in cloud optical depth
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
FSW	Flux and Clouds Regional Swath Product
GMT	Greenwich Mean Time
hPa	Hectopascal
LW	Longwave
METASS	Metadata for Synoptic SARB
MOA	Meteorological, Ozone, and Aerosol Product
MODIS	Moderate Resolution Imaging Spectrometer
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
PCPSS	Processing and Control Parameters for Synoptic SARB
QCSS	Quality Control Report for Synoptic SARB
SAGE	Stratospheric Aerosol and Gas Experiment
SARB	Surface and Atmospheric Radiation Budget
SRC	Surface Radiative Properties Climatology

SSF	Single Satellite Flux Product
SURFMAP	Surface Map Product
SW	Shortwave
SYN	Synoptic Product
TBD	To Be Determined
TOA	Top of Atmosphere
TRMM	Tropical Rainfall Measuring Mission
TSI	Time Space Interpolate Product