

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

## **Data Management System**

### **Compute Monthly and Regional TOA and SRB Averages (Subsystem 10.0)**

#### **Software Requirements Document**

**Release 1  
Version 1**

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## **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.

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## **1.0 Introduction**

The Clouds and the Earth's Radiant Energy System (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, which operated from 1984 through 1990 on the National Aeronautics and Space Administration's (NASA) Earth Radiation Budget Satellite (ERBS) and on the National Oceanic and Atmospheric Administration's (NOAA) operational weather satellites NOAA-9 and NOAA-10. 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.

### **1.1 Purpose and Objective of Document**

The purpose of this document is to serve as a basis for the design and to provide a complete set of requirements necessary to guide the development of the Monthly Regional Top-of-the-Atmosphere (TOA) and Surface Radiation Budget (SRB) Averages Subsystem (10.0). The intended audience consists of the following groups: the subsystem design team, testers, follow-on subsystems, and science reviewers. Additional information is provided to suggest guidelines for organizing the design efforts.

This document contains the following information:

- A brief overview of the process
- A description of key concepts
- A description of the requirements approach and any necessary trade-offs
- A description of each external interface
- An explanation of each mode the Subsystem can operate in
- The detailed functional requirements for the Subsystem
- A description of any design goals and constraints
- Identification of resource usage requirements

## 1.2 System Overview

The Monthly Regional TOA and SRB Averages Subsystem (10.0) computes averages of TOA longwave (LW) and shortwave (SW) fluxes, surface fluxes, and cloud properties on regional, zonal, and global spatial scales. Two methods are used to compute the regional total-sky flux averages. TOA flux estimates from both of the two methods are used to produce estimates of surface flux at all temporal and spatial scales using the TOA-to-surface flux parameterization schemes for shortwave and longwave described in the ERBE-Like Inversion to Instantaneous TOA and Surface Fluxes (Subsystem 2.0) ([Reference 1](#)).

The main input to Subsystem 10.0 is the Hourly Gridded Single Satellite TOA and Surface Fluxes and Clouds (SFC) product produced by Surface Gridding and Spatial Averaging Subsystem (9.0). SFC contains hourly single satellite flux and cloud properties averaged over 1.25-degree regions. Subsystem 10.0 produces Monthly Regional TOA and SRB Averages (SRBAVG). The process of producing these means involves several steps:

1. The ancillary geostationary data which are used in the interpolation of TOA fluxes are gridded to the CERES grid system and regionally and temporally sorted and merged.
2. The total-sky flux data are interpolated by two methods: the ERBE-like method and the geostationary data enhancement method ([Reference 2](#)).
3. Cloud property data are linearly interpolated.
4. Monthly and monthly hourly means are calculated from the interpolated fluxes and cloud properties on regional, zonal, and global scales.

## 2.0 Key Concepts

The following key concepts are embodied in the Monthly Regional TOA and SRB Averages Subsystem:

*Data Organization.* The primary input, SFC, consists of 1-hour averages for a month of CERES measurements for each observed region of the 1.25-degree equal-area grid. This month of data will be processed together. In addition, each region will be analyzed independently of all others.

*Merge Data.* If data from different instruments or different satellites are processed for the same month, these data are combined. When data exist for a given hour and region from more than one satellite or instrument, the data are averaged and rewritten in the SFC format. If data for a given hour and region are only from one satellite or instrument, the data are simply rewritten in the SFC format. The relevant parameters from SFC which are used in the averaging process are the total-sky LW and SW TOA fluxes, the clear-sky LW and SW TOA fluxes, the CERES-derived cloud information, the angular model scene types, the surface fluxes, and the surface-only data.

*Shared Functions.* In order to eliminate duplication of code and processing, Subsystem 10.0 will be able to perform two functions which can also be performed by Time Interpolation for Single and Multiple Satellites (7.1): the Regrid Geo process and the Generate Solar Declination Data process. Additionally, the Generate Weights and Flags process can also be performed by Monthly Regional, Zonal, and Global Radiative Fluxes and Cloud Properties Subsystem (8.0). If either of these three functions has already been performed by Subsystem 7.1, Subsystem 8.0, or Subsystem 10.0, then the last subsystem to run will only access the data produced by the other subsystem.

*Geostationary Data.* Geostationary data will most likely be the International Satellite Cloud Climatology Project (ISCCP) B3 or DX data. These data are provided at 3-hourly intervals at 0, 3, 6, ... , 21 GMT. These data will be sorted and averaged onto the CERES 1.25-degree equal-area grid. If this gridding has already been done by Subsystem 7.1, it does not need to be redone; access to the gridded data is all that is needed by the time interpolation process. These data will also have to be interpolated to produce gridded geostationary data at each local hour.

*Solar Information.* The solar declination angle and the distance corrections for the narrowband and broadband solar constants for each day of the year are produced for the interpolation process. If this information has already been produced by Subsystem 7.1, it does not need to be recreated; access to this information is all that is needed by the time interpolation process.

*Time Interpolation and Averaging.* Time interpolation and averaging are the main functions of Subsystem 10.0. Details of interpolation methods for LW and SW fluxes, window fluxes, cloud data, and surface-only parameters can be found in [Section 5.2.7.2.3.1.1](#) and in [5.2.7.2.3.1.3](#) through [5.2.7.2.3.1.7](#). Details of averaging methods can be found in [Section 5.2.7.2.3.2](#).

*Metadata and Error Handling.* Metadata and error handling will conform to the Earth Observing System Data and Information System (EOSDIS) operating environment requirements, which are currently being defined. Details regarding metadata and error handling have been deferred until more information on the operating environment is available.



*Data Quality.* All bad data are expected to have been eliminated from the input data products by the time that SRBAVG processing takes place. Several validation studies are planned by the CERES Science Team to determine the uncertainties in the interpolated cloud properties and surface and TOA fluxes. These efforts will be used to quantify the errors introduced into the time interpolation process and to develop improved techniques.

*Data Output.* At the close of processing, Subsystem 10.0 will have produced one SRBAVG product for the month containing regional, zonal, and global averages.

### 3.0 Requirements Approach and Tradeoffs

The purpose of this section is to examine the overall approach in gathering, analyzing, and synthesizing requirements and the trade-off processes used to arrive at the software requirements for this Subsystem.

The following issues were identified from the Algorithm Theoretical Basis Document for Subsystem 7 and apply to Subsystem 10.0 ([Reference 3](#)):

1. Geostationary data and polar-orbiting satellite radiance data are used for interpolation of fluxes and window radiances.

Rationale: This type of data provides enhanced temporal resolution. The measurements also provide information regarding variations in meteorology and cloudiness occurring between the times of the CERES observations. Several simulations have been performed which show that these data enhance the accuracy of time interpolation of broadband observations by decreasing root mean square error ([Reference 3](#)). Other advantages found from using the narrowband data in the above simulations were that the sampling effects were minimized and that it increased the accuracy of filling in the flux values for times between the CERES measurements.

2. The total-sky LW and SW interpolation will be performed using two different methods; the ERBE-like method found in the ERBE-like Averaging to Monthly TOA and Surface Fluxes Subsystem (3.0) ([Reference 4](#)) and the geostationary data enhanced method described in item 1 above.

Rationale: The ERBE-like interpolation method is used to provide a consistent data set for long-term climate studies. The geostationary data enhanced interpolation method significantly improves the accuracy of the diurnal modeling.

3. The clear-sky SW and LW interpolation is the same as the Method 1 of the total-sky interpolation.

Rationale: Since the CERES Project is geared towards studying the effects of clouds, there will be a significant improvement in the quality of clear-sky data. Therefore, the misclassifications of clear-sky scenes which occurred in the ERBE data should no longer be a problem and, hence, for Release 1 the idealized ERBE half-sine model will be used for interpolation of clear-sky LW over land regions.

4. The number of cloud properties interpolated varies depending on the cloud conditions of the two observed points between which the interpolation is performed.

Rationale: Only cloud amount is linearly interpolated when only one observation has a non-

zero cloud amount. All cloud properties are linearly interpolated when both observations have non-zero cloud amounts, with the exception of visible optical depth ([References 3, 5](#)).

## 4.0 External Interface Requirements

This section provides information on the interface requirements which must be satisfied between the system and each of its external input/output entities. These interfaces are depicted graphically in the Context Diagram (Figure 4-1). The subparagraphs following the context diagram provide the detailed requirements for each of the data interfaces represented in the diagram.

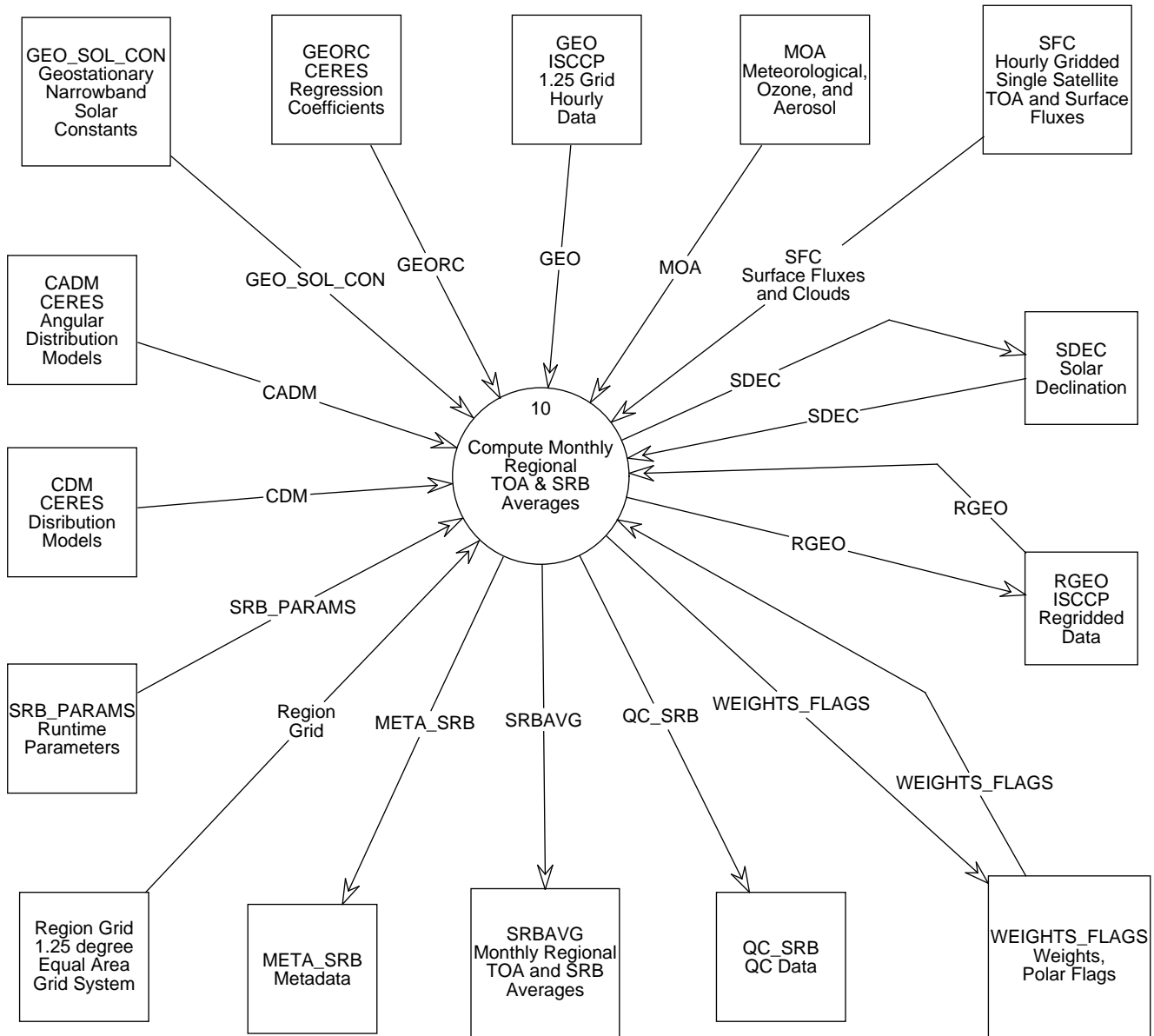


Figure 4-1. Context Diagram

## 4.1 Input

### 4.1.1 SFC Surface Fluxes and Clouds

The Hourly Gridded Single Satellite Fluxes and Clouds (SFC) archival data product contains hourly single satellite flux and cloud parameters averaged over 1.25-degree regions. Input to the Surface Gridding and Spatial Averaging Subsystem (9.0) is the Single Satellite CERES Footprint TOA and Surface Fluxes, Clouds archival data product. Each SFC contains data for a month, organized by region and time from a single CERES instrument mounted on one satellite. The product has a product header and multiple records; each record contains spatially averaged data for an individual region.

The major categories of data output on the SFC are:

- Region data
- Total-sky radiative fluxes at TOA and surface
- Clear-sky radiative fluxes at TOA and surface
- Column-averaged cloud properties
- Angular model scene classes
- Surface-only data

Details of this product can be found in the CERES Data Management System Data Products Catalog ([Reference 6](#)).

### 4.1.2 GEO

ISCCP produces B3 radiances, which are used for filling in unsampled portions of the globe during a particular 1-hour interval. The ISCCP B3 radiances are well enough defined that we do not need to make a further composite data structure to reformat them. In addition, these radiances are part of the Langley Research Center (LaRC) Distributed Active Archive Center (DAAC) archival responsibility.

The ISCCP B3 radiances consist of a window channel radiance (near 10.8 micrometers) and a visible channel radiance (near 0.68 micrometers) obtained from up to five geostationary satellites, as well as some data from the equivalent channels of the Advanced Very High Resolution Radiometer (AVHRR) and High Resolution Infrared Radiation Sounder (HIRS) instruments on the operational satellites. The radiances from each geostationary imager are sampled at about 32 km resolution every 3-hours. Where a geostationary (GEO) data source is not available (over India, primarily), the AVHRR data are processed into an equivalent format. Each geostationary satellite has a Sector Processing Center (SPC) that samples and formats the radiances. When they finish their work, the SPC sends the sampled and formatted radiance pairs to the Global Processing Center (GPC), where the radiances are normalized and reformatted into archival form. Because each SPC follows its own schedule, the global radiance sets may not be available on a schedule that is appropriate for CERES operations; the CERES Project will use the ISCCP DX radiance data as an alternate source. The GEO radiances contain two basic kinds of information:

1. Visible (near 0.68 micrometers) and Window (near 10.8 micrometers) Radiances sampled at 32 km spacing
2. Earth Location Information

These radiances have been normalized to a common set of locations on the Earth and corrected for gain drifts, insofar as possible. GEO is an external input data product retrieved from the EOSDIS DAAC at LaRC. Details of this product can be found in the CERES Data Management System Data Products Catalog ([Reference 6](#)).

### 4.1.3 MOA

The CERES archival product, Meteorological, Ozone, and Aerosol (MOA), formerly named Atmospheric Structures (ASTR), is produced by the CERES Regrid Humidity and Temperature Fields Subsystem (12.0). Each MOA file contains meteorological, ozone, and aerosol data for 1-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 the National Meteorological Center (NMC), Moderate Resolution Imaging Spectrometer (MODIS), Stratospheric Aerosol and Gas Experiment (SAGE), and various other satellites. These data arrive anywhere from four times daily to once a month and may have entirely different spatial and temporal resolutions than what the CERES system requires. The Regrid Humidity and Temperature Fields Subsystem interpolates these data temporally, horizontally, and vertically to conform with CERES processing requirements.

The MOA contains:

- Surface temperature and pressure
- Vertical profiles for up to 38 internal atmospheric levels of temperature, humidity, and geopotential height as a function of pressure level. The 38 internal atmospheric levels, in hPa, as requested by the CERES Clouds and SARB Working Groups are listed in [Table 4-1](#)
- Column precipitable water
- Vertical ozone profiles at 26 (of the 38) internal atmospheric levels
- Column ozone
- Total column aerosol
- Stratospheric aerosol

Table 4-1. MOA Internal Atmospheric Levels (in hPa)

| <b>Floating Levels</b> | <b>1000 to 875</b> | <b>850 to 725</b> | <b>700 to 450</b> | <b>400 to 225</b> | <b>200 to 70</b> | <b>50 to 1</b> |
|------------------------|--------------------|-------------------|-------------------|-------------------|------------------|----------------|
| 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               |                |

Details of this product can be found in the CERES Data Management System Data Products Catalog ([Reference 6](#)).

#### 4.1.4 GEORC

The Geostationary Regression Coefficients (GEORC) product contains regional narrowband - broadband regression coefficients that will be used with the narrowband data from the GEO data set to convert the narrowband fluxes to broadband fluxes. GEORC will contain two sets of four regression coefficients each, for every CERES grid box. One set of coefficients will be for LW flux while the second set will be for SW flux. Owing to seasonal variations in surface albedos and variations in regional cloud type, both sets of coefficients will need to be updated monthly. For Release 1, GEORC will be produced offline. For Release 2, GEORC will be generated in production, when data months are being processed sequentially, since 4 days of data from the previous month will be used to generate the regression coefficients for the current month being processed. When data months are being processed nonsequentially, GEORC will be produced offline.

#### 4.1.5 CADM

CERES Angular Distribution Models (CADMs) are inputs to the CERES radiative flux inversion process and are used to invert CERES unfiltered radiance measurements to SW, LW, and Window (WN) fluxes at the top-of-atmosphere. For Release 1, the CADM files will contain ERBE production Angular Distribution Models (ADMs). This file will include LW (limb darkening) models, SW (bidirectional) models, and SW and LW normalization constants. In Release 1 CERES software, the ERBE LW ADMs and LW normalization constants will be used to invert the WN channel unfiltered radiance measurements.

- The ERBE LW models are a function of the LW scene type, viewing zenith angle, the colatitude of the scanner target, and the season of the year.
- The ERBE LW normalization constants for linear interpolation are a function of the LW scene type and the colatitude of the scanner target.
- The ERBE SW models are a function of the SW scene type and three angles: viewing zenith, solar zenith, and the relative azimuth between the Sun and the satellite.
- The ERBE SW normalization constants for trilinear interpolation are a function of the SW scene type and the solar zenith angle.

The CERES Inversion Working Group will generate and maintain the CADMs. The CADMs will be updated for Release 3, after analyzing the results from approximately 18 months of CERES processing, using data from the CERES Rotating Azimuth Plane Scanner (RAPS) ([Reference 7](#)).

#### **4.1.6 CDM**

The CERES Directional Models (CDM) contains the appropriate directional albedo models used in the modeling of albedo in the monthly averaging process of CERES data. It is derived from the angular bidirectional models. It consists of models for clear-sky scenes over the five geotypes of ocean, land, snow, desert, and land/ocean; partly cloudy and mostly cloudy scenes over the three geotypes of ocean, land or desert, and land/ocean mix; and an overcast scene.

#### **4.1.7 GEO SOL CON**

The Geostationary Solar Constant (GEO\_SOL\_CON) product is an ancillary input to the CERES Monthly Regional TOA and SRB Averages Subsystem. It contains a parameter which gives the number of satellites which are being used in the ISCCP data and the narrowband solar constants for each satellite.

This product is classified as internal ancillary. It will change whenever the composition of satellites used in ISCCP data collection changes.

#### **4.1.8 Region Grid**

Region Grid contains information about the grid system or regions over which spatial averaging of SFC parameters occurs. This is an equal area grid of 1.25-degree regions. There are a total of 26,410 regions over the globe, organized into 144 latitudinal zones. The zones are numbered consecutively starting with 1 at the North Pole, and progressing to 144 at the South Pole. The regions in each zone are numbered consecutively starting with 1 in zone 1 at the Greenwich meridian, and progressing eastward around the globe.



The grid system is defined by two arrays, each of length 144. The array RegWidth contains the width in degrees longitude of the regions in each of the 144 latitudinal zones. All regions in a given zone have the same width. The array InitRegNum contains the region number of the first region in each of the 144 latitudinal zones.

#### **4.1.9 SRB PARAMS**

The run-time parameters (SRB\_PARAMS) product consists of run-time parameters necessary for this Subsystem; subsets of the parameters below are used by the different processes. It is an ancillary input to the CERES Monthly Regional TOA and SRB Averages Subsystem. It consists of parameters needed to identify and process the data. The parameters in this product include but are not limited to:

1. Satellite(s) identification
2. The data month being processed
3. The number of days in the data month being processed to identify missing days
4. The data year being processed
5. Geostationary satellite identifications
6. The number of geostationary data products available

This product is classified for this project as internal ancillary and, therefore, will be generated as needed to process the data. It is not yet clear whether CERES or EOSDIS will produce SRB\_PARAMS.

## **4.2 Output**

### **4.2.1 SRBAVG**

The SRBAVG product contains monthly and monthly hourly regional, zonal, and global averages of the TOA and surface LW and SW fluxes and the observed cloud conditions for each 1.25-degree equal-area region. This product differs from the AVG product in three ways. First, the surface fluxes have been calculated from the TOA fluxes using parameterizations provided by the CERES Science Team, instead of using the models provided by the Surface and Atmospheric Radiation Budget (SARB) Subsystem. Secondly, no flux fields are calculated at levels between TOA and the surface. Lastly, the regional total-sky fluxes are calculated using two different temporal interpolation techniques. Both results are stored on the product.

SRBAVG is an archival product produced by this Subsystem. One product is produced for each instrument and one for each required combination of instruments. At the TRMM launch, this product will be produced in a validation mode for the first 18 months. During these 18 months, the CERES Science Team will derive a production quality set of Angular Distribution Models which are needed to produce the LW and SW instantaneous fluxes.

SRBAVG is composed of the following structures on a regional, zonal, and global basis:

- Location data
- Total-Sky radiative fluxes at TOA and surface
- Clear-Sky radiative fluxes at TOA and surface
- Column-Averaged Cloud properties for five weighting schemes:  
(TOA SW, TOA LW, SFC LW, Liquid Water Path (LWP) and Ice Water Path (IWP))
- Angular model scene types
- Surface-only data

Details of this product can be found in the CERES Data Management System Data Products Catalog ([Reference 6](#)).

#### **4.2.2 QC SRB**

QC\_SRB indicates all of the Quality Control (QC) information for Subsystem 10.0 processes. The QC information for Generate Solar Declination consists of the solar declination angles and the distance corrections for the broadband solar constants. The QC information for Regrid Geo is TBD. The QC information for Merge Multi-Satellite Data consists of input parameters, error messages, and statistics for sample regions. The QC information for Perform Interpolation and Averaging consists of input parameters, error messages, a summary of the hours containing data, statistics for sample regions, and a global processing summary. The QC for Generate Weights and Flags contains the weighting factors and the polar flags. The QC information for Compute Zonal and Global Averages contains zonal and global averages.

#### **4.2.3 META SRB**

META\_SRB consists of all the metadata (TBD) produced by the Subsystem 10.0 processes.

### **4.3 Input/Output**

#### **4.3.1 RGEO**

The regridded geostationary (RGEO) data contains ISCCP geostationary data which have been gridded to the CERES 1.25-degree grid and sorted by region and time. The geostationary data contained in RGEO are the visible and window narrowband radiance data, satellite identification, number of points, solar zenith angle, viewing zenith angle, azimuth angle, time information, and region number.

### **4.3.2 SDEC**

The Solar Declination (SDEC) product contains the tabulated values of solar declination angles and the distance corrections to the solar constant. These values are required for each day of each year and are always referenced to  $0^H 0^M 0^S$  Universal time (UT). A FORTRAN program for generating the solar declination angles and the distance corrections to the solar constant from an analytic Earth Ephemeris already exists.

### **4.3.3 WEIGHTS FLAGS**

WEIGHTS\_FLAGS contains the polar flags and the area weighting factors. The polar flags are day-night indicators needed in this Subsystem to identify those regions within approximately 23.5 degrees of the poles that experience continuous darkness or continuous light at certain times of the year. These regions are treated differently from those which always experience day-night cycles when calculating zonal and global averages. The polar flags vary monthly and are calculated for an entire year.

The area weighting factors are values needed in this Subsystem to account for the small differences in the areas of regions in different latitude zones. Only one weighting factor is needed for each latitudinal band. The area weighting factors do not change; they may be calculated once and used repeatedly.

A FORTRAN program already exists to calculate the polar flags and area weighting factors, but it will be modified for the CERES grid system.

## 5.0 Requirements Specification

This section provides the specification of requirements which must be satisfied by the system. Included are functional requirements, internal data elements, performance requirements, and implementation constraints. In addition, this section identifies design goals which will be addressed during the design phase and estimates for the processing resources required by the Subsystem. The design goals are distinguished from the requirements by the fact that it is not possible to include formal tests for the design goals in the system Test Plan.

### 5.1 Operating Modes

There will be two normal modes of operation for this process. In both of these modes, Control Process will be executed; it will then determine which operating mode will be used. A description of the operating modes follows:

1. Single instrument mode will be used when data from a single instrument become available. In this mode, processes Perform Interpolation and Averaging and Compute Zonal and Global Averages will be executed. Processes Regrid Geo, Generate Solar Declination Data, and Generate Weights and Flags will be executed independently as their required data become available, or the data produced by these processes in previous runs will be accessed.
2. Multiple instrument mode will be used when data from at least two instruments have been processed through single instrument mode. In this mode, processes Merge Multi-Satellite Data, Perform Interpolation and Averaging, and Compute Zonal and Global Averages will be executed. The data produced by processes Regrid Geo, Generate Solar Declination Data, and Generate Weights and Flags in previous runs will be accessed.

### 5.2 Functional Requirements

This section identifies the specific functional requirements for the Subsystem, which are depicted graphically in data flow diagrams. A top-level Subsystem context diagram was previously depicted in Section 4. The first level decomposition of the Subsystem is shown in the Data Flow Diagram for Level 0 (Figure 5-1). A discussion of the functionality shown in Figure 5-1 can be found in the System Overview (Section 1.2). The subparagraphs following the Data Flow Diagram for Level 0 provide the detailed requirements (process specifications, or "P-specs") for each of the processes shown in the figure. Processes that can be further decomposed into subprocesses are indicated by the inclusion of an "\*" in the diagram beside the process number. If there are no further subprocesses, the diagram will include a "p" beside the process number. The process specifications will be used to define the testing requirements for the Subsystem and will be documented in a Subsystem Test Plan and Procedures document.

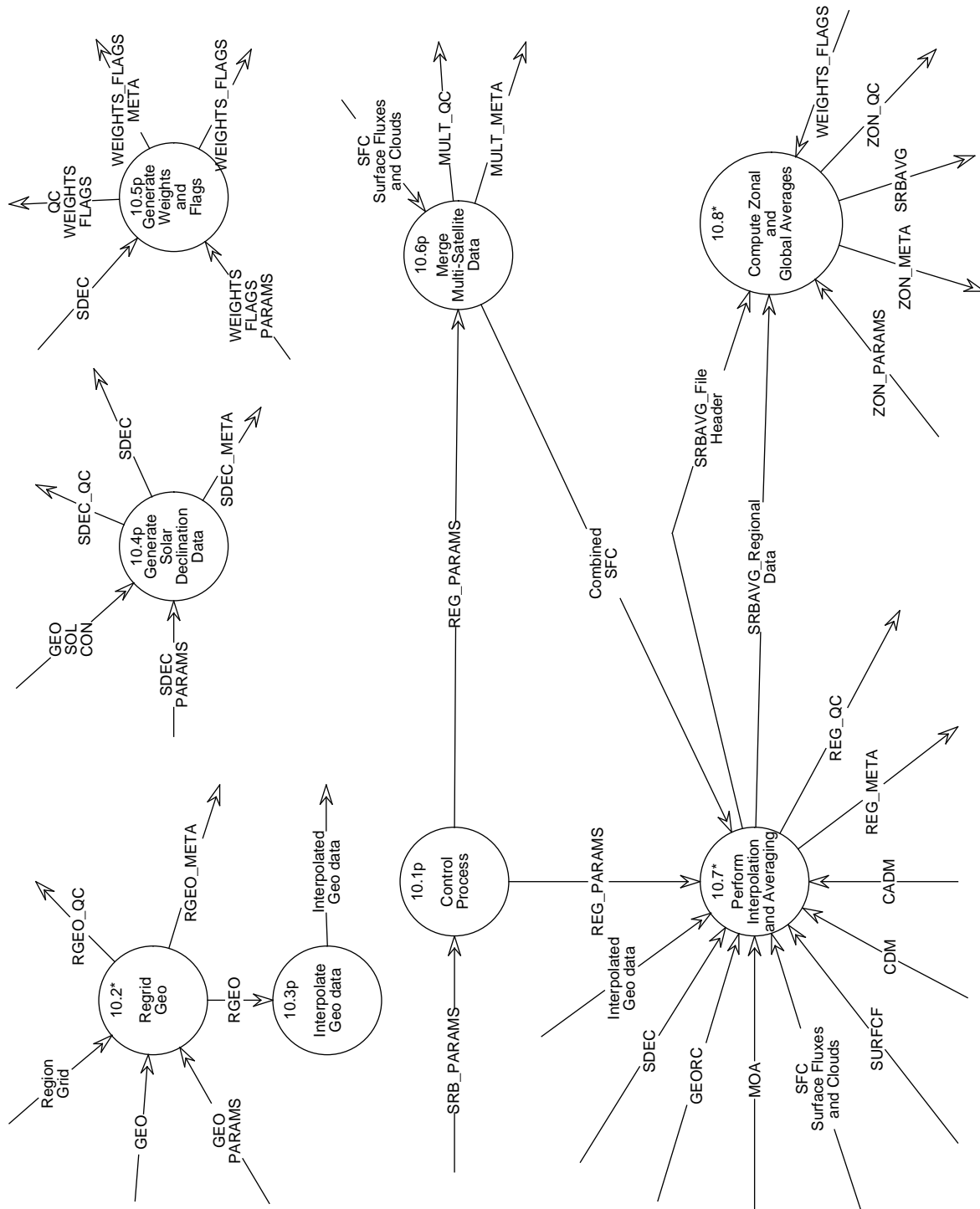


Figure 5-1. Data Flow Diagram for Level 0

## 5.2.1 Control Process - Process 10.1

### Input Data Flows

SRB PARAMS

### Output Data Flows

REG PARAMS

### Process Specification (Figure 5-1):

This process shall:

1. Check for the existence of regrided geostationary data. If these data do not exist, the process Regrid Geo will be executed.
2. Check for the existence of solar declination data. If these data do not exist, the process Generate Solar Declination Data will be executed.
3. Check for the existence of weights and flags. If these data do not exist, the process Generate Weights and Flags will be executed.
4. Examine satellite identification:
  - a) If satellite identification indicates only a single instrument, then initialize and execute the Perform Interpolation and Averaging process.
  - b) If satellite identification indicates multiple instruments, then initialize and execute the Merge Multi-Satellite Data process.

## 5.2.2 Regrid Geo - Process 10.2

### Input Data Flows

GEO

GEO PARAMS

Region Grid

### Output Data Flows

RGEO

RGEO META

RGEO QC

### Process Description (Figure 5-1):

This process will perform the following subprocesses:

1. Check the availability of ISCCP data via the GEO\_PARAMS file, if not available, then write an error message in the RGEO QC report and quit the process.
2. If data are available, read in the ISCCP geostationary narrowband data.
3. Grid the 3-hourly, 32-kilometer resolution geostationary radiance pixel data to the CERES 1.25 equal area grid and sort by time.
4. Create the regrided geostationary product (RGEO) and output the RGEO quality control report and metadata.

The decomposition of this function is shown in [Figure 5-2](#).

### **5.2.2.1 Read Geo Data - Process 10.2.1**

#### **Input Data Flows**

GEO  
GEO PARAMS

#### **Output Data Flows**

Geo Radiance Data

#### **Process Specification** ([Figure 5-2](#)):

This process shall:

1. Check the availability of the geostationary data and obtain other necessary processing parameters via the GEO\_PARAMS file. If geostationary data are not available, write an error message in the RGEO QC report and quit the process.
2. If geostationary data are available, read in one month of geostationary data which are measured every 3 hours (0,3,6, ..., 21 GMT).
3. Validate the data headers as well as each image id.
4. Obtain and store necessary information (TBD) from each image id such as the number of radiance data records.
5. Output the Geo Radiance Data (shortwave radiances, longwave (window) radiances, satellite identification, region number, and time and angle information) to process Sort/ Grid Geo Data.

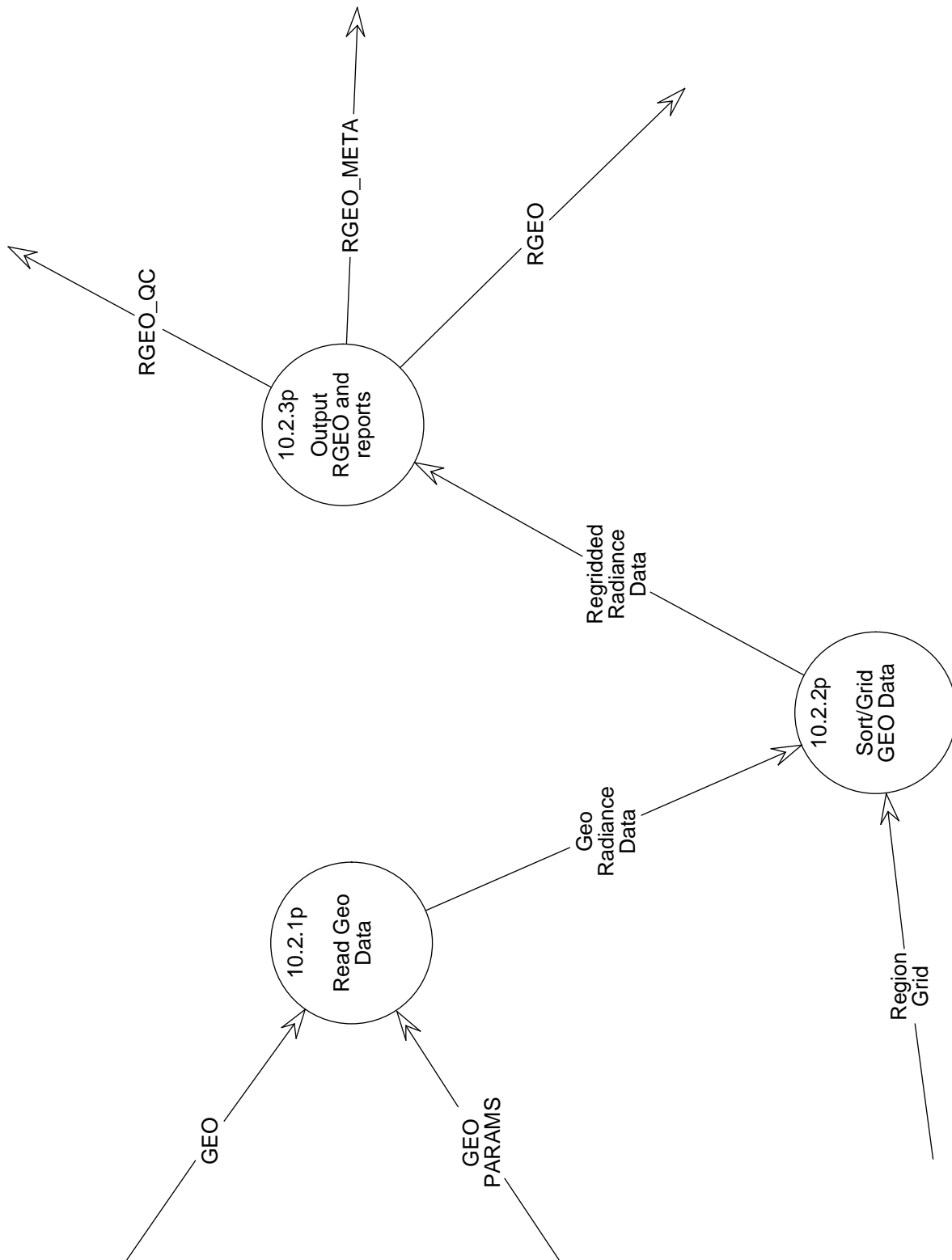


Figure 5-2. Data Flow Diagram for Regrid Geo



### **5.2.2.2 Sort/Grid GEO Data - Process 10.2.2**

#### **Input Data Flows**

Geo Radiance Data  
Region Grid

#### **Output Data Flows**

Regridded Radiance Data

#### **Process Specification** (Figure 5-2):

This process shall:

1. Access the Geo Radiance Data.
2. Grid the Geo Radiance Data to the CERES 1.25-degree equal area grid.
3. Sort the 3-hourly, 32-kilometer resolution radiance pixel data for the entire month by region and time.

### **5.2.2.3 Output RGEO and reports - Process 10.2.3**

#### **Input Data Flows**

Regridded Radiance Data

#### **Output Data Flows**

RGEO  
RGEO META  
RGEO QC

#### **Process Specification** (Figure 5-2):

This process shall:

1. Create header information for RGEO.
2. Output the header information, the Regridded Radiance Data to form the RGEO product.
3. Output QC report with TBD information.
4. Output metadata.

### **5.2.3 Interpolate Geo data - Process 10.3**

#### **Input Data Flows**

RGEO

#### **Output Data Flows**

Interpolated Geo data

#### **Process Specification** (Figure 5-1):

This process shall:

1. Interpolate geostationary data to local solar hour.

### **5.2.4 Generate Solar Declination Data - Process 10.4**

#### **Input Data Flows**

GEO SOL CON  
SDEC PARAMS

#### **Output Data Flows**

SDEC  
SDEC META  
SDEC QC

#### **Process Specification** (Figure 5-1):

This process shall:

1. Input date in calendar format.
2. For every day of a given year:
  - a) Calculate the solar declination angle.
  - b) Calculate the distance corrections to the broadband solar constant.
3. Create product SDEC.
4. Write solar declination angles and distance corrections to QC report.
5. Write metadata (TBD).

## 5.2.5 Generate Weights and Flags - Process 10.5

### Input Data Flows

SDEC  
WEIGHTS FLAGS PARAMS

### Output Data Flows

QC WEIGHTS FLAGS  
WEIGHTS FLAGS  
WEIGHTS FLAGS META

### Process Specification (Figure 5-1):

This process shall:

1. Generate polar flags which identify the regions which experience continuous sunlight or darkness during certain times of the year.
2. Generate area weighting factors for each latitude band in order to account for differences in the areas of regions in different latitude zones.

## 5.2.6 Merge Multi-Satellite Data - Process 10.6

### Input Data Flows

REG PARAMS  
SFC Surface Fluxes and Clouds

### Output Data Flows

Combined SFC  
MULT META  
MULT QC

### Process Specification (Figure 5-1):

This process shall:

1. Read input parameters for merging process.
2. Read SFC data files for each instrument.
3. Merge data from different instruments; i.e., when data exist for a given hour and region from more than one satellite, average the data.
4. Output merged data.

5. Output Quality Control information.
6. Output metadata.

### **5.2.7 Perform Interpolation and Averaging - Process 10.7**

#### **Input Data Flows**

CADM  
CDM  
Combined SFC  
GEORC  
Interpolated Geo data  
MOA  
REG PARAMS  
SDEC  
SFC Surface Fluxes and Clouds

#### **Output Data Flows**

REG META  
REG QC  
SRBAVG File Header  
SRBAVG Regional Data

#### **Process Description** ([Figure 5-1](#)):

This process will perform the following subprocesses:

1. Input a month of hourly gridded data.
2. Perform interpolation and averaging by latitude band.
3. Produce quality control reports and metadata for the interpolation and averaging process.

The decomposition of this function is shown in [Figure 5-3](#).

#### **5.2.7.1 Input Month of Gridded Data - Process 10.7.1**

#### **Input Data Flows**

REG PARAMS  
SFC Surface Fluxes and Clouds

#### **Output Data Flows**

SFC File Header

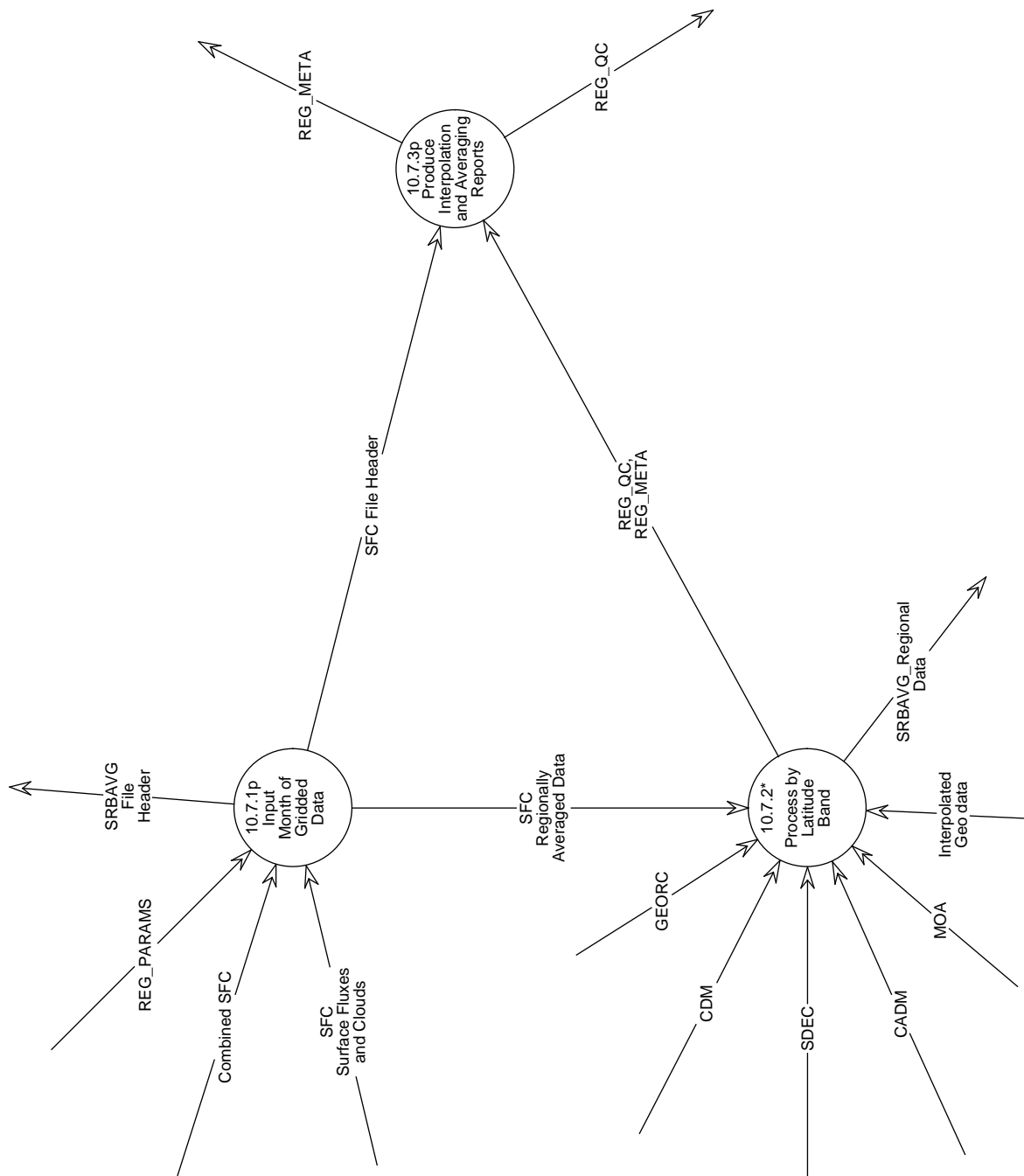


Figure 5-3. Data Flow Diagram for Perform Interpolation and Averaging

SFC Regionally Averaged Data  
SRBAVG File Header

**Process Specification** (Figure 5-3):

This process shall:

1. Verify that the input header information agrees with input parameters for the data month, year, and instrument identification.
2. Output the input headers to the process Produce Interpolation and Averaging Reports.
3. Generate headers for the output product SRBAVG using month, year, and instrument, and output these headers to process Compute Zonal and Global Averages.
4. Output SFC Regionally Averaged Data to process Process by Latitude Band.

**5.2.7.2 Process by Latitude Band - Process 10.7.2**

**Input Data Flows**

CADM  
CDM  
GEORC  
Interpolated Geo data  
MOA  
SDEC  
SFC Regionally Averaged Data

**Output Data Flows**

REG META  
REG QC  
SRBAVG Regional Data

**Process Description** (Figure 5-3):

This process will perform the following subprocesses:

1. Process the Solar Information
2. Calculate SW Diurnal Models
3. Process by Region Number

The decomposition of this function is shown in Figure 5-4.

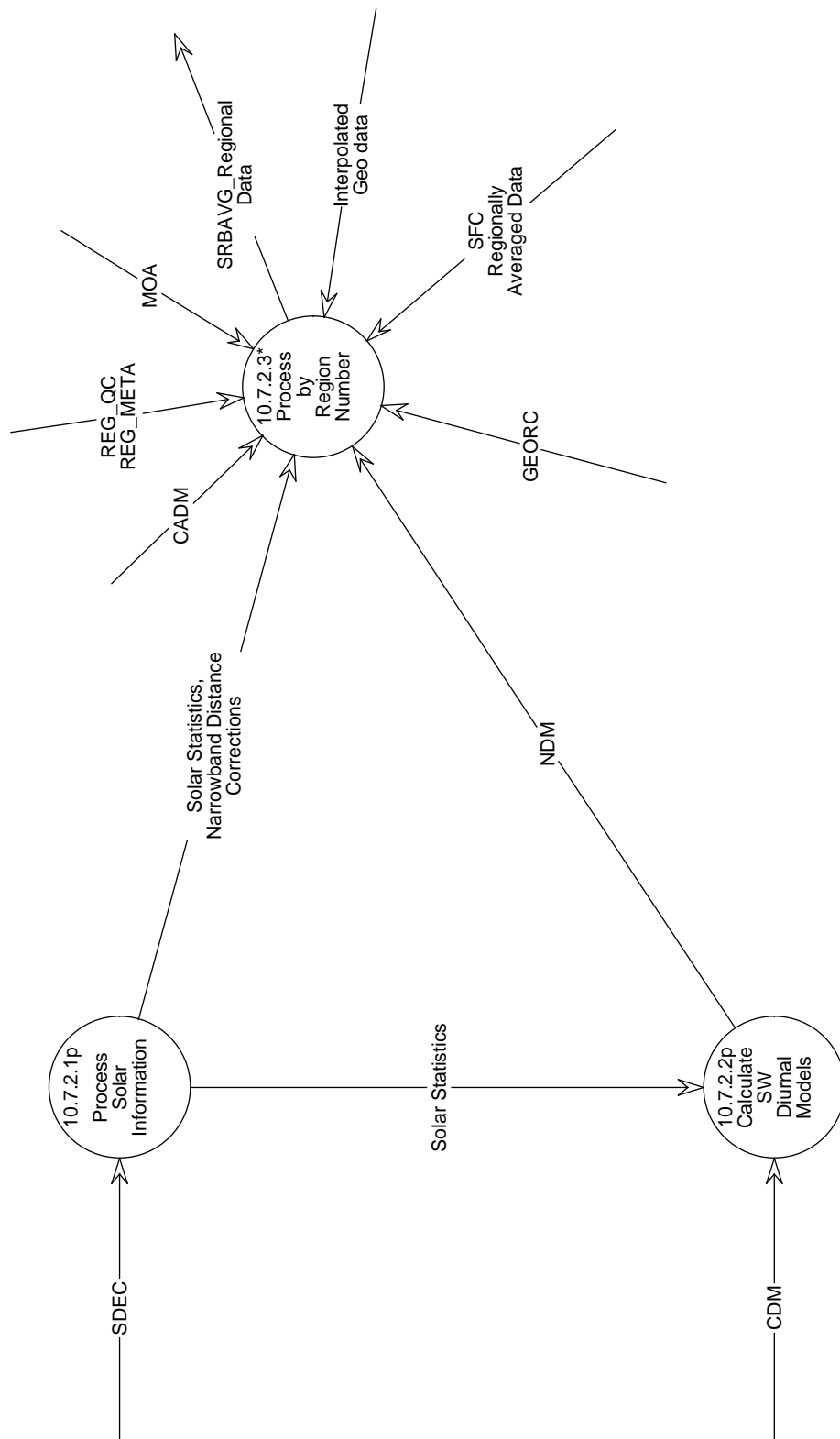


Figure 5-4. Data Flow Diagram for Process by Latitude Band

### 5.2.7.2.1 Process Solar Information - Process 10.7.2.1

#### Input Data Flows

SDEC

#### Output Data Flows

Narrowband Distance Corrections

Solar Statistics

#### Process Specification (Figure 5-4):

This process shall:

1. Compute sine and cosine of latitude band.
2. For each day in the month:
  - a) Compute the sine and cosine of the solar declination angle.
  - b) For each hour in the day:
    - 1) Compute the cosine of the solar zenith angle at the local solar half hour for the local half hour.
    - 2) Sum the cosine of the solar zenith angle up for the day.
    - 3) Compute the solar incidence value for the hour box by multiplying the cosine of the solar zenith angle for the half hour by the distance corrected broadband solar constant.
  - c) Determine if the Sun came up for the day, i.e., summed cosine of solar zenith angle for day is greater than 0.0000001.
  - d) Compute the half-day length since the half-sine fit for clear-sky longwave will not be used if the half-day length is less than 1-hour.
  - e) Calculate the first and last daylight hours using the half-day length.
  - f) Compute the integrated solar incidence for the day.



3. Output the solar data to processes Calculate SW Diurnal Models and Process by Region Number.

This process performs similar functions as the subroutine, COSZSC, found in the ERBE code; algorithms may be modified to suit the CERES Project.

#### **5.2.7.2.2 Calculate SW Diurnal Models - Process 10.7.2.2**

##### **Input Data Flows**

CDM  
Solar Statistics

##### **Output Data Flows**

NDM

##### **Process Specification** (Figure 5-4):

This process shall:

1. For each hour of the month:
  - a) Determine if the cosine of the solar zenith angle is less than or equal to zero; if so, set the modeled directional values to zero.
  - b) If the cosine is greater than zero and less than 0.05, set the modeled directional values to those values corresponding to a cosine of 0.05.
  - c) If the cosine is greater than or equal to 0.95, set the modeled directional values to those values corresponding to a cosine of 0.95.
  - d) Compute the indices which point to the nearest high and low modeled directional model values read from CDM.
  - e) Compute the interpolation factor.
  - f) Interpolate between high and low modeled values to compute the modeled directional values for each scene type.
2. Output the normalized diurnal model (NDM) to Process by Region Number.

This process performs similar functions as subroutine, DIMODS, found in the ERBE code; algorithms may be modified to suit the CERES Project.

### 5.2.7.2.3 Process by Region Number - Process 10.7.2.3

#### Input Data Flows

CADM  
GEORC  
Interpolated Geo data  
MOA  
NDM  
Narrowband Distance Corrections  
SFC Regionally Averaged Data  
Solar Statistics

#### Output Data Flows

SRBAVG Regional Data

#### Process Description (Figure 5-4):

This process will perform the following subprocesses:

1. Read a regions worth of data.
2. Perform necessary interpolation and averaging for that particular region.

The decomposition of this function is shown in [Figure 5-5](#).

#### 5.2.7.2.3.1 Perform Interpolation - Process 10.7.2.3.1

#### Input Data Flows

CADM  
GEORC  
Interpolated Geo data  
MOA  
NDM  
Narrowband Distance Corrections  
SFC Regionally Averaged Data  
Solar Statistics

#### Output Data Flows

Interpolated Regional Parameters

#### Process Description (Figure 5-5):

This process will perform the following subprocesses:

1. Interpolate the cloud data structures

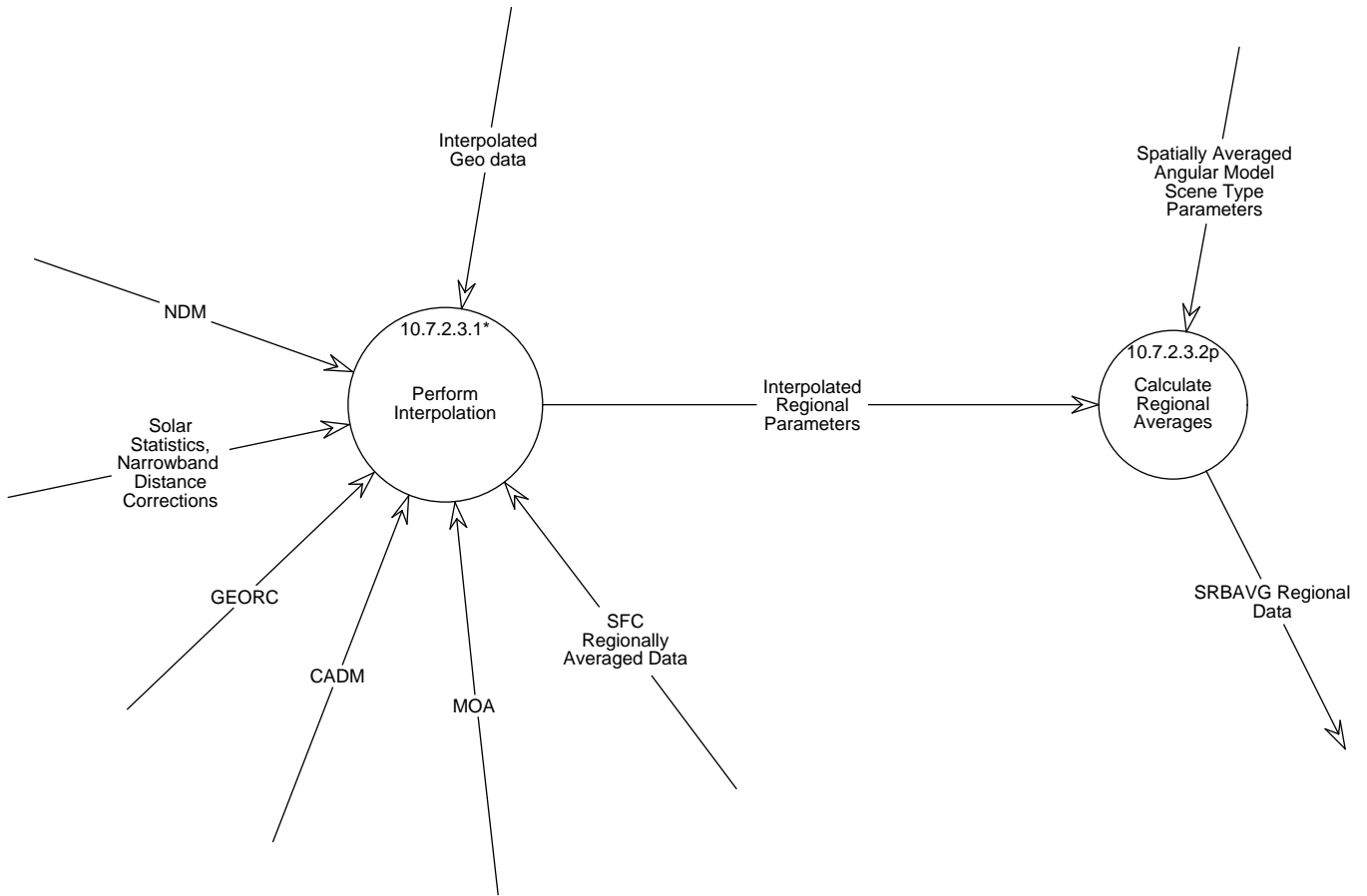


Figure 5-5. Data Flow Diagram for Process by Region Number

2. Convert narrowband radiances to broadband fluxes
3. Interpolate LW flux
4. Interpolate SW flux
5. Interpolate window flux
6. Interpolate surface-only data

7. Interpolate surface flux

8. Gather all of the interpolated data and pass it to process Calculate Regional Averages

The decomposition of this function is shown in [Figure 5-6](#).

#### **5.2.7.2.3.1.1 Interpolate Cloud Data Structures - Process 10.7.2.3.1.1**

##### **Input Data Flows**

Spatially Averaged Angular Model Scene Type Parameters

Spatially Averaged SFC Weighted Column-Averaged Cloud Properties

##### **Output Data Flows**

Interpolated Angular Model Scene Types

Interpolated Cloud Data

##### **Process Specification** ([Figure 5-6](#)):

This process shall:

1. Linearly interpolate to local solar hours the Column-Averaged Cloud Properties using the following strategy:
  - a) If both the observation times contain a non-zero cloud amount for a given cloud pressure category, the means and standard deviations of all the cloud properties are linearly interpolated with respect to time, with the exception of visible optical depth.
  - b) The visible optical depth is recalculated using the interpolated values of liquid (or ice) water path and particle size using the relationships described in [Reference 5](#).
  - c) If only one of the two observation times contains a non-zero cloud amount for the cloud category, then only the cloud amount is linearly interpolated. The remaining properties are assumed to be constant throughout the time period.
2. Linearly interpolate to all local solar hours the Angular Model Scene Class Albedos and scene fractions.

#### **5.2.7.2.3.1.2 Convert Narrowband Radiances to Broadband Fluxes - Process 10.7.2.3.1.2**

##### **Input Data Flows**

CADM

GEORC

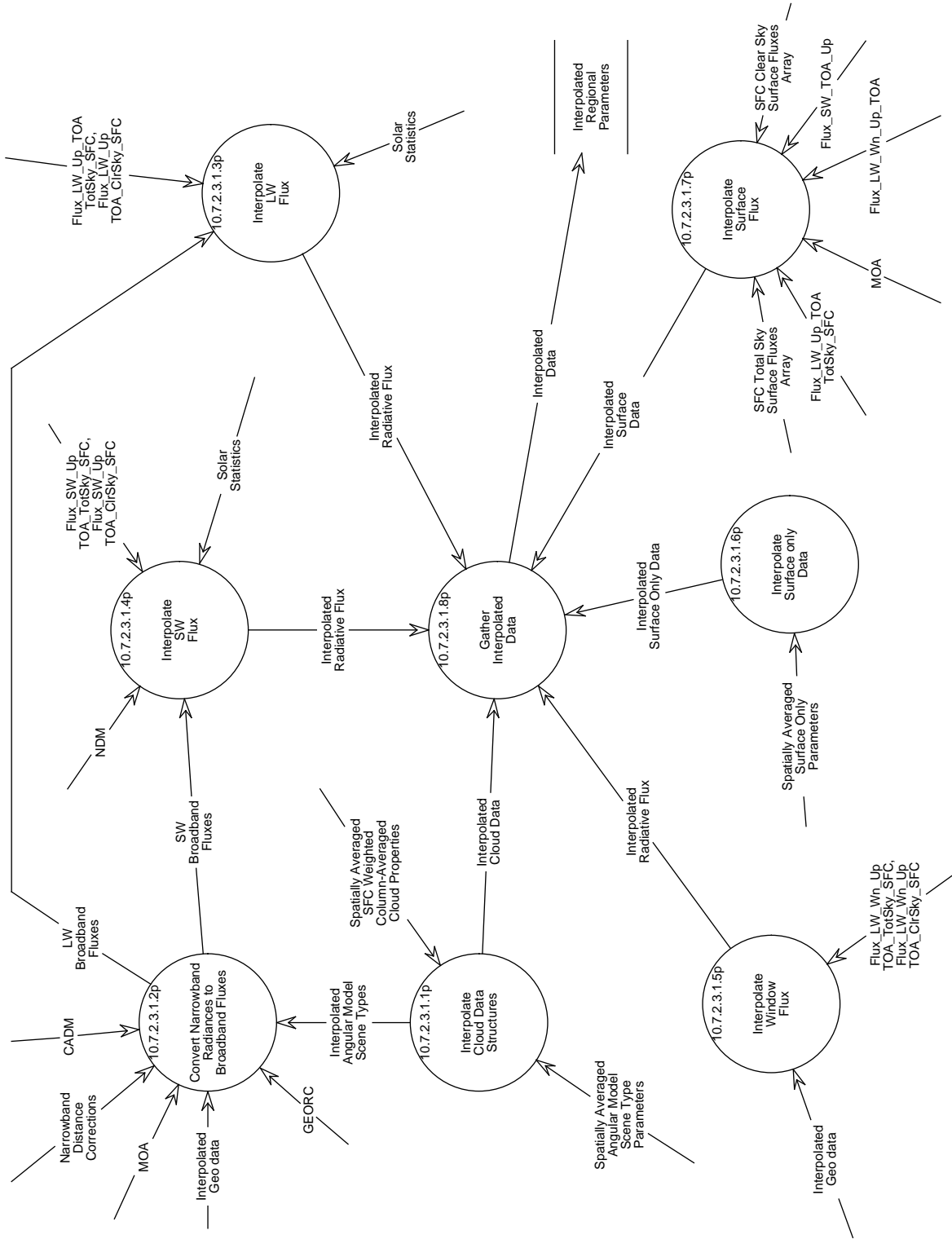


Figure 5-6. Data Flow Diagram for Perform Interpolation

Interpolated Angular Model Scene Types  
Interpolated Geo data  
MOA  
Narrowband Distance Corrections

### Output Data Flows

LW Broadband Fluxes  
SW Broadband Fluxes

### Process Specification (Figure 5-6):

This process shall convert narrowband radiances to broadband fluxes based on the following methods when geostationary data are available:

#### 1. Total-sky Longwave:

- a) The LW narrowband radiance from the geostationary data is converted to narrowband flux by the following equation:

$$F_{nb} = 6.18 \cdot \gamma(\theta)^{-1} \cdot I_{nb} \quad (\text{Reference 3})$$

where  $I_{nb}$  is the LW narrowband radiance,  $\gamma(\theta)$  is the longwave limb-darkening function at viewing zenith angle  $\theta$ , and 6.18 represents the product of the limb darkening function integrated over an entire hemisphere and the narrowband spectral interval.

- b) The LW narrowband flux is then converted to LW broadband flux by applying the following regression equation:

$$F_{bb} = a_0 + a_1 F_{nb} + a_2 F_{nb}^2 + a_3 F_{nb} \ln(rh) \quad (\text{Reference 3})$$

where  $F_{bb}$  is the LW broadband flux,  $F_{nb}$  is the narrowband flux,  $rh$  is the column-averaged relative humidity, and  $a_i$  are the derived coefficients.

#### 2. Clear-sky Longwave:

The LW narrowband radiance data will not be used in the interpolation of clear-sky longwave data; therefore, there is no need to convert narrowband radiance data to broadband fluxes.

#### 3. Total-sky Shortwave:

- a) Calculate the narrowband albedo from the narrowband observations using scene fraction and CERES broadband albedo weighted anisotropic factors. The narrowband

albedo is calculated in the following equation:

$$\alpha_{nb} = (\Pi_{nb} / (S_v \cos \theta_0)) / \left[ \frac{\sum_{i=1}^{12} R_i \alpha_i f_i}{\sum_{i=1}^{12} \alpha_i f_i} \right] \quad (\text{Reference 3})$$

Where  $\Pi_{nb}$  is the mean narrowband SW radiance within the CERES region,  $S_v$  is the Earth-Sun distance corrected narrowband solar constant,  $\theta_0$  is the solar zenith angle at the center of the region at the synoptic time, and  $\alpha_i$ ,  $f_i$ , and  $R_i$  are the albedo, scene fraction, and bidirectional anisotropic factor, respectively, for ADM class  $i$ .

- b) The narrowband radiances are then converted to broadband fluxes using the following regression equation:

$$\alpha_{bb} = b_0 + b_1 \alpha_{nb} + b_2 \alpha_{nb}^2 + b_3 \ln(\sec(\theta_0)) \quad (\text{Reference 3})$$

where  $\alpha_{nb}$  is the narrowband albedo,  $\alpha_{bb}$  is the broadband albedo, and  $\theta_0$  is the solar zenith angle at the center of the region at the synoptic time, and  $b_i$  are the derived coefficients. Separate regressions are performed for ocean and land regions.

#### 4. Clear-sky Shortwave:

The SW narrowband radiance data will not be used in the interpolation of clear-sky shortwave data; therefore, there is no need to convert narrowband radiance data to broadband fluxes.

### 5.2.7.2.3.1.3 Interpolate LW Flux - Process 10.7.2.3.1.3

#### Input Data Flows

Flux LW Up TOA ClrSky SFC  
 Flux LW Up TOA TotSky SFC  
 LW Broadband Fluxes  
 Solar Statistics

#### Output Data Flows

Interpolated Radiative Flux

#### Process Specification (Figure 5-6):

This process shall:

1. Interpolate the total-sky TOA LW flux using the two methods described below:
  - a) Method 1 -- Reference (4, 8)

- 1) For the ocean, coastal, and snow covered regions, linear interpolation is used to provide a value for each hour box not observed by CERES. At the beginning of the month, all hours preceding the first observation are filled with the value from the first observed time of the month. This is similar for the end of the month.
- 2) For land and desert regions, for any day in which an observation is made during the daylight hours and during the preceding and following nights, the LW flux for the remaining hours of the day are modeled by fitting a half-sine curve to the observations. On days that do not have the required observations or if any daylight observations of LW flux are less than the nighttime values or if the resultant half-sine curve has a negative amplitude, the interpolation performed is linear.

b) Method 2: -- Reference (3)

The simulated broadband measurements (derived LW flux from process Convert Narrowband Radiances to Broadband Fluxes) for the region are normalized to the nearest CERES observation of flux. For points between two CERES measurements, the normalization is linearly scaled inversely by the time difference between the hour in question and the times of the observations.

2. Interpolate the clear-sky TOA LW flux:

Similar to Method 1 of the above algorithms with the exception that clear-sky TOA LW flux is necessary at each local time; in the case when the measurements are not available at the particular time, the clear-sky fits from the nearest day with data are used.

#### 5.2.7.2.3.1.4 Interpolate SW Flux - Process 10.7.2.3.1.4

##### Input Data Flows

Flux SW Up TOA ClrSky SFC  
 Flux SW Up TOA TotSky SFC  
 NDM  
 SW Broadband Fluxes  
 Solar Statistics

##### Output Data Flows

Interpolated Radiative Flux

##### Process Specification (Figure 5-6):

This process shall:



1. Interpolate the total-sky TOA SW flux using both of the following methods:

a) Method 1:

- 1) For each hour box with an observation, a separate albedo is calculated for each of the cloud classifications.
- 2) Measured values are adjusted to the nearest local solar half hour.
- 3) For a given surface type and cloud cover category, (i.e., scene type for selecting an ADM), the albedos at time  $t$  and  $t'$  may be specified in terms of a reference value at overhead Sun:

$$\alpha_i(\mu(t)) = \alpha_i(\mu_0 = 1) \cdot \delta_i(\mu(t)) \quad (\text{Reference 4})$$

where  $\mu$  is the cosine of the solar zenith angle, and  $\delta_i$  is the normalized ADM function for scene type  $i$ . The albedo at any time  $t'$  (e.g., at the local solar half hour) can be calculated in terms of known quantities at the time of observation,  $t_{\text{obs}}$ :

$$\alpha_i(t') = \alpha_i(\mu(t_{\text{obs}})) \cdot \frac{\delta_i(\mu(t'))}{\delta_i(\mu(t_{\text{obs}}))} \quad (\text{Reference 4})$$

- 4) For days with only one measurement of SW flux, each of the cloud type albedos from the hour of observation is modeled to all daylight hours using equation 3.4 of Reference 4 and the appropriate NDMs. The albedos are then recombined by weighting each cloud type albedo with the appropriate areal coverage fraction to obtain the mean albedo for each hour for the entire region.
- 5) For days with more than one measurement, all daylight hours preceding the first and following the last measurement assume constant cloud class from the nearest measurement. These hours are modeled as in the single measurement case. For hours between two measurements, the cloud type albedos are calculated from each surrounding measurement and the appropriate NDMs. The total albedo for each hour between the two measurements is calculated by inversely weighting the two estimates by the time from the hour of interest.
- 6) The SW flux is calculated by multiplying the total albedo by the solar flux for that time.

b) Method 2: -- Reference (3)

- 1) Read in the converted broadband fluxes.

- 2) Normalize the time series to the CERES broadband observations.
- 3) Linearly interpolate the measurements using the cloud amounts and albedos in order to select the proper anisotropic factor.

2. Interpolate the clear-sky TOA SW flux:

Interpolate the CERES data using the clear-sky ADMs appropriate to the regional type surface using the Method 1 of total-sky SW interpolation.

#### **5.2.7.2.3.1.5 Interpolate Window Flux - Process 10.7.2.3.1.5**

##### **Input Data Flows**

Flux LW Wn Up TOA ClrSky SFC  
Flux LW Wn Up TOA TotSky SFC  
Interpolated Geo data

##### **Output Data Flows**

Interpolated Radiative Flux

##### **Process Specification** (Figure 5-6):

This process shall:

1. Interpolate the window flux:
  - a) Method 2 of the total-sky TOA LW flux interpolation is used without the narrowband to broadband regression
  - b) The geostationary radiances will be normalized to the CERES measurements in order to correct for any differences in the spectral intervals or the calibration of the instruments.

#### **5.2.7.2.3.1.6 Interpolate Surface only Data - Process 10.7.2.3.1.6**

##### **Input Data Flows**

Spatially Averaged Surface-Only Parameters

##### **Output Data Flows**

Interpolated Surface-Only Data

##### **Process Specification** (Figure 5-6):

This process shall:

1. Interpolate the surface-only parameters using a TBD method

#### **5.2.7.2.3.1.7 Interpolate Surface Flux - Process 10.7.2.3.1.7**

##### **Input Data Flows**

SFC Clear-Sky Surface Fluxes Array  
SFC Total-Sky Surface Fluxes Array

##### **Output Data Flows**

Interpolated Surface Data

##### **Process Specification** ([Figure 5-6](#)):

This process shall use three algorithms defined in CERES Inversion to Instantaneous Fluxes and Empirical Estimates of Surface Radiation Budget (Subsystems 4.5 and 4.6) ([Reference 9](#)).

#### **5.2.7.2.3.1.8 Gather Interpolated Data - Process 10.7.2.3.1.8**

##### **Input Data Flows**

Interpolated Cloud Data  
Interpolated Radiative Flux  
Interpolated Surface Data  
Interpolated Surface-Only Data

##### **Output Data Flows**

Interpolated Data

##### **Process Specification** ([Figure 5-6](#)):

This process shall:

1. Gather the interpolated TOA total-sky and clear-sky LW flux data.
2. Gather the interpolated TOA total-sky and clear-sky SW flux data.
3. Gather the interpolated cloud data.
4. Gather the interpolated surface-only parameters.
5. Gather the interpolated window fluxes.
6. Send above data to process Produce SRBAVG.

### **5.2.7.2.3.2 Calculate Regional Averages - Process 10.7.2.3.2**

#### **Input Data Flows**

Interpolated Regional Parameters  
Spatially Averaged Angular Model Scene Type Parameters

#### **Output Data Flows**

SRBAVG Regional Data

#### **Process Specification (Figure 5-5):**

This process shall:

1. Calculate averages of the column averaged cloud properties and angular model scene class.
2. Calculate averages of the interpolated total-sky and clear-sky LW and SW flux. Since the interpolation is performed using two methods, there will be two sets of monthly and monthly-hourly averages.
3. Calculate averages of window fluxes.
4. Calculate averages of surface SW and LW fluxes.
5. Calculate averages of surface-only data.

### **5.2.7.3 Produce Interpolation and Averaging Reports - Process 10.7.3**

#### **Input Data Flows**

REG META  
REG QC  
SFC File Header

#### **Output Data Flows**

REG META  
REG QC

#### **Process Specification (Figure 5-3):**

This process shall:

1. Write metadata (TBD).
2. Write an error message report to the quality control report.

3. Write a global processing summary to the quality control report.
4. Write a summary of the hours with data to the quality control report.
5. Write a statistics summary to the quality control report.

Note: If it is necessary to write the output to different files, an output file summary will be written to the quality control report. The output file summary will indicate which region of the globe resides on a given science output data file.

### **5.2.8 Compute Zonal and Global Averages - Process 10.8**

#### **Input Data Flows**

SRBAVG File Header  
SRBAVG Regional Data  
WEIGHTS FLAGS  
ZON PARAMS

#### **Output Data Flows**

SRBAVG  
ZON META  
ZON QC

#### **Process Description** ([Figure 5-1](#)):

This process will perform the following subprocesses:

1. Input the SRBAVG Regional Data and the SRBAVG File Header.
2. Calculate the zonal averages.
3. Calculate the global averages.
4. Produce the output product, SRBAVG.
5. Produce the QC and metadata reports.

The decomposition of this function is shown in [Figure 5-7](#).

#### **5.2.8.1 Input Regional Data - Process 10.8.1**

#### **Input Data Flows**

SRBAVG Regional Data

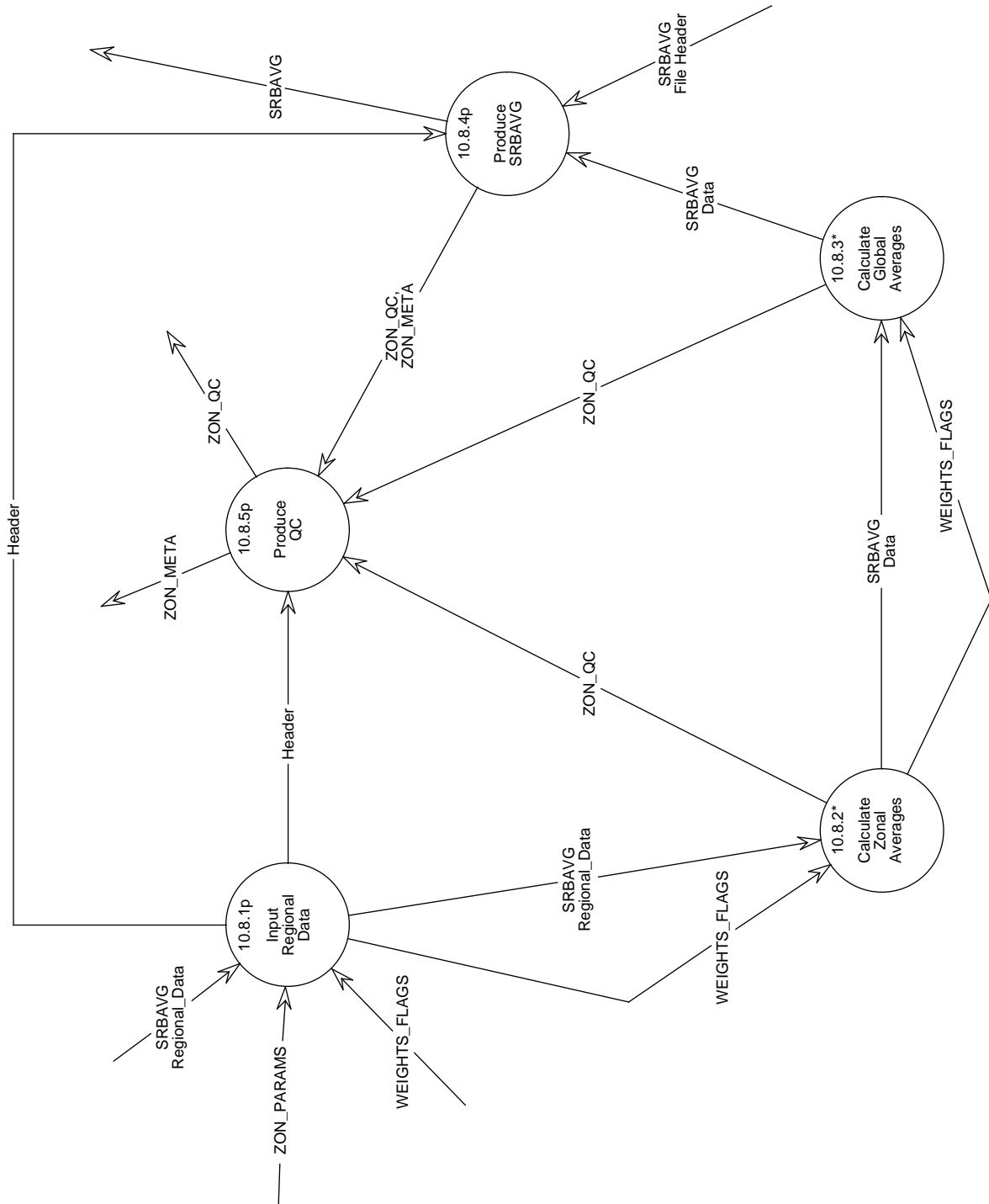


Figure 5-7. Data Flow Diagram for Compute Zonal and Global Averages

WEIGHTS FLAGS  
ZON PARAMS

**Output Data Flows**

Header  
SRBAVG Regional Data  
WEIGHTS FLAGS

**Process Specification** (Figure 5-7):

This process shall:

1. Read the regional data, validate the header, and output the header to processes Produce QC and Produce SRBAVG.
2. Read the polar flags and area weighting factors, and validate the header.
3. Read the run-time parameters.

The process performs similar functions as the subroutines, FILINT, INITL, and FILDRV, found in the ERBE code; algorithms may be modified to suit the CERES Project.

**5.2.8.2 Calculate Zonal Averages - Process 10.8.2**

**Input Data Flows**

SRBAVG Regional Data  
WEIGHTS FLAGS

**Output Data Flows**

SRBAVG Data  
WEIGHTS FLAGS  
ZON QC

**Process Description** (Figure 5-7):

This process will perform the following subprocesses:

1. Initialize zonal processing.
2. Apply the zonal nonpolar algorithm.
3. Apply the zonal polar algorithm.

The decomposition of this function is shown in Figure 5-8.

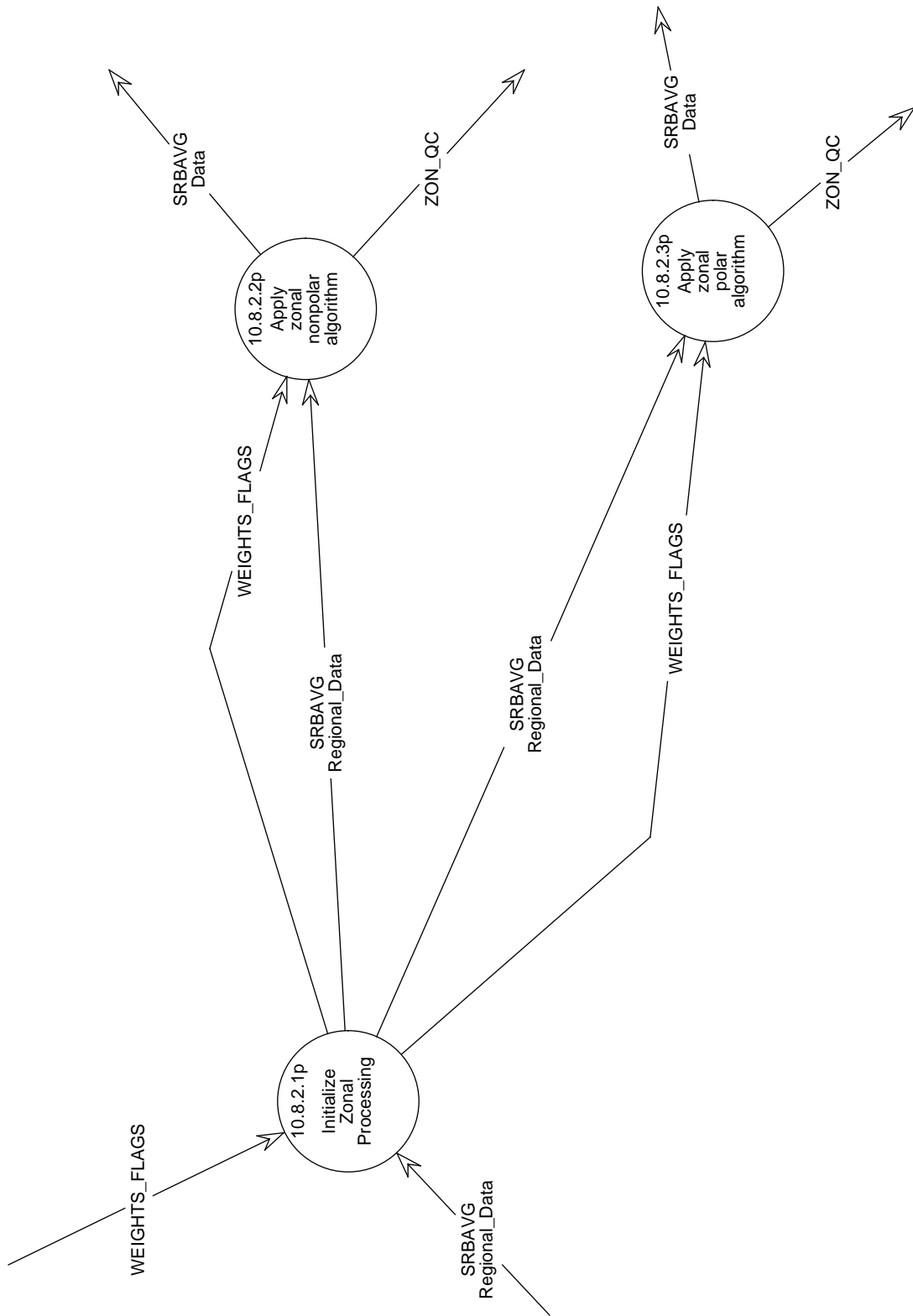


Figure 5-8. Data Flow Diagram for Calculate Zonal Averages



### 5.2.8.2.1 Initialize Zonal Processing - Process 10.8.2.1

#### Input Data Flows

SRBAVG Regional Data  
WEIGHTS FLAGS

#### Output Data Flows

SRBAVG Regional Data  
WEIGHTS FLAGS

#### Process Specification (Figure 5-8):

This process shall:

1. Determine the number of regions per latitude.
2. Determine if the colatitude is a polar colatitude.
3. Apply the polar or nonpolar algorithm.
4. Calculate the zonal averages for the specified spatial resolution.

This process performs similar functions as the subroutine, ZONE, found in the ERBE code; functions may be modified to suit the CERES Project.

### 5.2.8.2.2 Apply zonal nonpolar algorithm - Process 10.8.2.2

#### Input Data Flows

SRBAVG Regional Data  
WEIGHTS FLAGS

#### Output Data Flows

SRBAVG Data  
ZON QC

#### Process Specification (Figure 5-8):

This process shall:

1. Apply weighting factors and sum the grand monthly and the monthly hourly longwave, shortwave, cloud properties, surface data, and solar incidence values.
2. Sum the number of hours that contain data.
3. Output QC information.

This process performs similar functions as the subroutines, NPOLAR and ZONREP, found in the ERBE code; functions may be modified to suit the CERES Project.

### **5.2.8.2.3 Apply zonal polar algorithm - Process 10.8.2.3**

#### **Input Data Flows**

SRBAVG Regional Data  
WEIGHTS FLAGS

#### **Output Data Flows**

SRBAVG Data  
ZON QC

#### **Process Specification** (Figure 5-8):

This process shall:

1. Apply weighting factors and sum the grand monthly and monthly hourly solar incidence, flux values, cloud properties, and surface data.
2. Sum the number of hours that contain data.
3. Output QC information.

This process performs similar functions as the subroutines, POLAR and ZONREP, found in the ERBE code; functions may be modified to suit the CERES Project.

### **5.2.8.3 Calculate Global Averages - Process 10.8.3**

#### **Input Data Flows**

SRBAVG Data  
WEIGHTS FLAGS

#### **Output Data Flows**

SRBAVG Data  
ZON QC

#### **Process Description** (Figure 5-7):

This process will perform the following subprocesses:

1. Initialize global processing.
2. Apply the global nonpolar algorithm.
3. Apply the global polar algorithm.

The decomposition of this function is shown in [Figure 5-9](#).

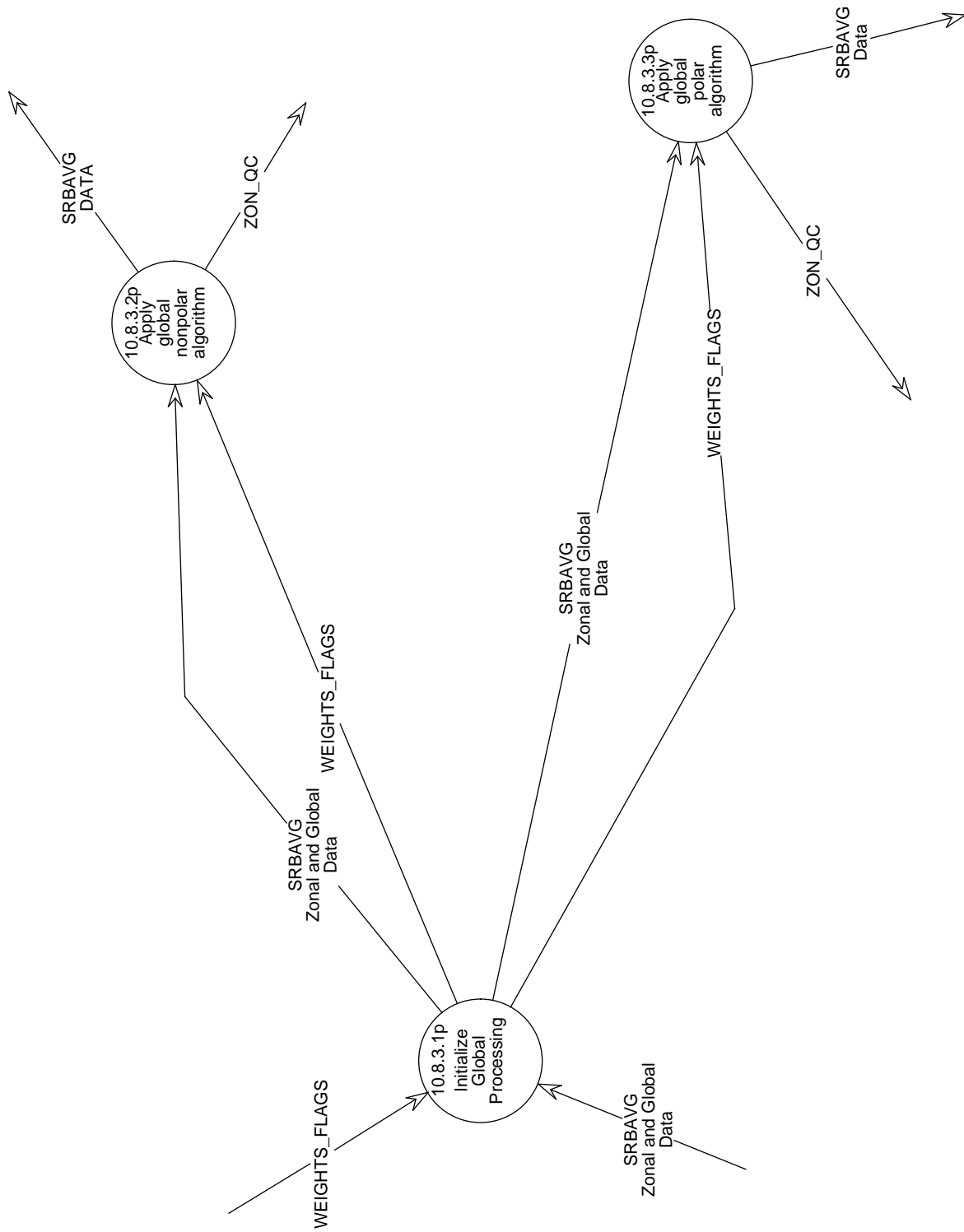


Figure 5-9. Data Flow Diagram for Calculate Global Averages

### 5.2.8.3.1 Initialize Global Processing - Process 10.8.3.1

#### Input Data Flows

SRBAVG Zonal and Global Data  
WEIGHTS FLAGS

#### Output Data Flows

SRBAVG Zonal and Global Data  
WEIGHTS FLAGS

#### Process Specification (Figure 5-9):

This process shall:

1. Apply the global polar or nonpolar algorithm.
2. Calculate the global average using the zonal averages from the specified spatial resolution.
3. Output QC information.

This function performs similar functions as the subroutine, GLOBE, found in the ERBE code; functions may be modified to suit the CERES Project.

### 5.2.8.3.2 Apply global nonpolar algorithm - Process 10.8.3.2

#### Input Data Flows

SRBAVG Zonal and Global Data  
WEIGHTS FLAGS

#### Output Data Flows

SRBAVG DATA  
ZON QC

#### Process Specification (Figure 5-9):

This process shall:

1. Apply area weighting factors and sum the grand monthly and the monthly hourly LW, SW, and incidence values.
2. Sum the number of hours that contain data.
3. Output QC information.

This process performs similar functions as the subroutines, NPOLAR and GLBREP, of the ERBE code; functions may be modified to suit the CERES Project.

### **5.2.8.3.3 Apply global polar algorithm - Process 10.8.3.3**

#### **Input Data Flows**

SRBAVG Zonal and Global Data  
WEIGHTS FLAGS

#### **Output Data Flows**

SRBAVG Data  
ZON QC

#### **Process Specification** (Figure 5-9):

To accumulate data for records which are in the polar regions, this process shall:

1. Determine from polar flags if the input values are nighttime values.
2. Apply the area weighting factors to the grand monthly and monthly hourly solar incidence values.
3. Sum the daily flux values, and monthly hourly flux values.
4. Output QC information.

This process performs similar functions as the subroutines, POLAR and GLBREP, of the ERBE code; functions may be modified to suit the CERES Project.

### **5.2.8.4 Produce SRBAVG - Process 10.8.4**

#### **Input Data Flows**

Header  
SRBAVG Data  
SRBAVG File Header

#### **Output Data Flows**

SRBAVG  
ZON META  
ZON QC

#### **Process Specification** (Figure 5-7):

This process shall:

1. Write header to output product, SRBAVG.
2. Format in Heirarchical Data Format (HDF).
3. Output data product, SRBAVG, only if there were no error messages.
4. Provide the necessary QC and metadata information from the data product to process Produce QC.

#### **5.2.8.5 Produce QC - Process 10.8.5**

##### **Input Data Flows**

Header  
ZON META  
ZON QC

##### **Output Data Flows**

ZON META  
ZON QC

##### **Process Specification** (Figure 5-7):

This process shall:

1. Write metadata (TBD).
2. Write an error message report to the QC report.
3. Write a global processing summary to the QC report.
4. Write a summary of regions with data to the QC report.
5. Write a summary of global and zonal averages.
6. Write a statistics summary to the QC report.

Note: If it is necessary to write the output to different files, an output file summary will be written to the QC report. The output file summary will indicate which region of the globe resides on a given science output data file.

### **5.3 Design Goals and Constraints**

The following are considered to be the design goals for this Subsystem:

1. Flexibility of code so as to be reusable for multiple instrument processing.
2. Inclusion of and modifications to certain routines of the ERBE FORTRAN code in order to minimize coding efforts.
3. Code improvements through lessons learned from the ERBE UNIX conversion. ([Reference 10](#))

The following are considered to be the implementation constraints for this Subsystem:

1. The availability and suitability of geostationary data is a concern for this Subsystem. This is due to the timeliness issue of the ISCCP DX data; there will almost certainly be a delay in obtaining the data since the cloud parameters need to be calculated by ISCCP. The B3 data is more readily available on a near real-time basis, but it does not contain any cloud information.
2. Data gaps in the ISCCP product are also a concern. This is due to the fact that the Indian Satellite (INSAT) data are often not available and the ISCCP products do not include SW data for solar zenith angles over 72.5 degrees, which limits the data being used for the SW interpolation process.
3. Regressions that are to be used to produce the broadband measurements have to be derived monthly. This is due to the seasonal variations in surface albedos and variations in regional cloud type. The regressions will be done in production when processing data months sequentially; 4 days of data from the previous month are used to produce the regression coefficients for the current month. When processing data months nonsequentially, the regressions will be done offline.
4. If the source of the narrowband data is not from ISCCP, then the narrowband radiances may have to be calibrated for each of the geostationary satellites; procedures will have to be developed for this purpose.
5. The EOSDIS Toolkit shall be used for the input/output calling sequences and aid in statistical and graphical calculations. ([Reference 11](#))
6. The data shall be organized using Hierarchical Data Format (HDF) format.
7. Metadata and handling of such shall be determined by the EOSDIS Toolkit ([Reference 11](#)).

## 5.4 Resource Use

The SRBAVG product will be produced once for every month of satellite data. A separate combined-instrument product will be produced with the same frequency for each data month. The estimated product size for SRBAVG is 564.4 megabytes (MB) or approximately 564 MB for a month's worth of satellite data.

The Central Processing Unit (CPU) processing load has been estimated for a Sun SPARC 2, based on ERBE experience ([Reference 12](#)), to be 65 hours for a month's worth of satellite data.

## References

The following documents are referenced herein and are directly applicable to this document:

1. Clouds and the Earth's Radiant Energy System (CERES), Algorithm Theoretical Basis Document, ERBE-like Inversion to Instantaneous TOA and Surface Fluxes (Subsystem 2.0), Release 1.1, April 1994.
2. Clouds and the Earth's Radiant Energy System (CERES), Algorithm Theoretical Basis Document, Monthly Regional TOA and Surface Radiation Budget (Subsystem 10.0), Release 1.1, April 1994.
3. 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, April 1994.
4. Clouds and the Earth's Radiant Energy System (CERES), Algorithm Theoretical Basis Document, ERBE-like Averaging to Monthly TOA and Surface Fluxes (Subsystem 3.0), Release 1.1, April 1994.
5. Clouds and the Earth's Radiant Energy System (CERES), Algorithm Theoretical Basis Document, Cloud Optical Property Retrieval (Subsystem 4.3), Release 1.1, April 1994.
6. CERES Data Management System Data Products Catalog, Release 1, July 1994.
7. Clouds and the Earth's Radiant Energy System (CERES), Algorithm Theoretical Basis Document, CERES Inversion to Instantaneous TOA Fluxes (Subsystem 4.5), Release 1.1, April 1994
8. Earth Radiation Budget Experiment (ERBE), Data Management System Reference Manual, Volume VI - Daily Data Base and Monthly Time/Space Averaging, November, 1986.
9. CERES Instantaneous Inversion to TOA Fluxes and Empirical Estimates of Surface Radiation Budget (Subsystem 4.5 and 4.6), CERES Data Management System Software Requirements Document, Release 1, NASA Langley Research Center, August 1994.
10. ERBE-Like Inversion to Instantaneous TOA and Surface Fluxes (Subsystem 2.0), CERES Data Management System Software Requirements Document, Release 1, NASA Langley Research Center, August 1994.
11. PGS Toolkit Users Guide for the ECS Project, Hughes Applied Information Systems, Version 1 Final, May 1994.
12. Clouds and the Earth's Radiant Energy System (CERES), Algorithm Theoretical Basis Document, CERES Data Processing System Objectives and Architecture(System Volume 0), Release 1.1, April 1994.



## Abbreviations, Acronyms, and Symbols

|         |  |
|---------|--|
| ADM     | Angular Distribution Models                        |
| ASTR    | Atmospheric Structures                             |
| AVHRR   | Advanced Very High Resolution Radiometer           |
| CADM    | CERES Angular Distribution Models                  |
| CDM     | CERES Directional Models                           |
| CERES   | Clouds and Earth Radiant Energy System             |
| CPU     | Central Processing Unit                            |
| DAAC    | Distributed Active Archive Center                  |
| ECS     | EOSDIS Core System                                 |
| EOS     | Earth Observing System                             |
| EOSDIS  | Earth Observing System Data and Information System |
| ERBE    | Earth Radiation Budget Experiment                  |
| ERBS    | Earth Radiation Budget Satellite                   |
| FORTRAN | FORmula TRANslation                                |
| FSW     | Hourly Gridded Single Satellite Fluxes and Clouds  |
| GEO     | Geostationary data                                 |
| GEORC   | GEO Regression Coefficients                        |
| GMT     | Greenwich Mean Time                                |
| GPC     | Global Processing Center                           |
| HDF     | Heirarchical Data Format                           |
| HIRS    | High Resolution Infrared Radio Sounder             |
| hPa     | hectoPascal  |
| ISCCP   | International Satellite Cloud Climatology Project  |
| IWP     | Ice Water Path                                     |
| LaRC    | Langley Research Center                            |
| LW      | Longwave   |
| LWP     | Liquid Water Path                                  |
| MB      | Megabyte   |
| MOA     | Meteorological, Ozone, and Aerosol                 |
| MODIS   | Moderate Resolution Imaging Spectrometer           |
| N/A     | Not Applicable                                     |
| NDM     | Normalized Diurnal Model                           |
| NMC     | National Meteorological Center                     |

|        |  |
|--------|--|
| NOAA   | National Oceanic and Atmospheric Administration        |
| PGS    | Product Generation System                              |
| QC     | Quality Control  |
| RAPS   | Rotating Azimuth Plane Scanner                         |
| RGEO   | Regridded Geostationary data                           |
| SAGE   | Stratospheric Aerosol and Gas Experiment               |
| SARB   | Surface and Atmospheric Radiation Budget               |
| SDEC   | Solar Declination                                      |
| SFC    | Hourly Gridded Single Satellite TOA and Surface Fluxes |
| SPC    | Sector Processing Center                               |
| SRB    | Surface Radiation Budget                               |
| SRBAVG | Monthly and Regional TOA and SRB Averages, 1.25 Grid   |
| SW     | Shortwave  |
| TBD    | To Be Determined                                       |
| TOA    | Top-of-Atmosphere                                      |
| TRMM   | Tropical Rainfall Measuring Mission (joint US-Japan)   |
| TSI    | Time Space Interpolation of clouds and TOA fluxes      |
| UT     | Universal time   |
| WN     | Window   |

## **List of Tables**

Table 4-1. MOA Internal Atmospheric Levels (in hPa) 10