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

Data Management System

Software Requirements Document

Surface Gridding and Spatial Averaging
(Subsystem 9.0)

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 Software Requirements Document (SRD) is to provide a basis for the design of the CERES Surface Gridding and Spatial Averaging (SGSA) Subsystem (Subsystem 9.0). The intended audience for this document is the CERES Data Management Team and the CERES Subsystem 9 Working Group.

The objective of this document is to provide a complete set of Release 1 requirements to guide the development of the Subsystem. Each functional requirement is described by a process specification (p-spec) that corresponds to a process shown in one of the data flow diagrams. Each requirement is identified by use of the word "shall," and is preceded by a number in square brackets. This number, which is called the requirement number, is used to identify and to track the requirements. The Subsystem Design Team will use these numbers to ensure that the subsystem design has addressed all of the requirements. The test team will use these numbers to identify requirements for testing, and to track the test results.

Release 1 software will be delivered to the Langley Distributed Active Archive Center (DAAC). Revisions to this Software Requirements Document will be incorporated into the Release 2 SRD, which will be published after the Release 1 software becomes operational.

This document contains:

- a brief overview of the Subsystem
- a description of the key concepts embodied in the Subsystem

- a discussion of the requirements approach and tradeoffs that guided the development of the requirements documented here
- a description of each external interface
- a discussion of the expected operating modes of the Subsystem
- a detailed discussion of the functional requirements identified for this Subsystem
- a discussion of design goals and constraints
- an estimate of Subsystem resource requirements
- a list of references
- a list of acronyms and abbreviations

1.2 System Overview

The Surface Gridding and Spatial Averaging Subsystem provides the transformation from instantaneous, instrument-referenced data to spatially-averaged Earth-referenced data. The primary input to this Subsystem is the Single Satellite TOA, Surface Flux, and Cloud Pixels (SSF) data product, which is an hourly collection of CERES footprints containing radiative fluxes and cloud information. The primary output of this Subsystem is the Hourly Gridded Single Satellite TOA and Surface Fluxes (SFC) data product, which contains radiative fluxes and cloud properties spatially averaged by regional hour box. Details of SSF and SFC are included in the CERES Data Management System Data Products Catalog (Reference 1).

This Subsystem performs two major functions: gridding and spatial averaging. The gridding function assigns CERES footprints to the appropriate regional hour box. Regional hour boxes have a 1.25-degree resolution. The spatial averaging function computes spatial averages of the various radiative flux parameters and cloud properties over each regional hour box. Flux parameter averages are calculated for the top-of-the-atmosphere (TOA) and the surface. After passing through this Subsystem, the CERES data lose their traceability to specific CERES measurements.

2.0 Key Concepts

The following key concepts are embodied in the Surface Gridding and Spatial Averaging Subsystem:

Grid System.   This Subsystem uses the same grid that was defined by Subsystem 6.0 (Reference 2. Subsystem 6.0).   This is the CERES grid system that is used for CERES Subsystems 6, 7, 8, 9, and 10. For Release 1, a 1.25-degree equal area grid that reduces distortion of the grid boxes at high latitudes is used. The grid system is only approximately equal area, as there must be an integral number of regions in each latitude zone.

Regional Hour Boxes. In addition to gridding CERES footprints based on geographic location of the footprint, this Subsystem assigns CERES footprints to regional hour boxes based on the local time of observation of the footprint. A regional hour box is simply a region at a particular hour of time. There are 744 regional hour boxes per region for a 31-day month. For a given region, regional hour box 1 encompasses the period from midnight to 1:00 a.m. on the first day of the month, regional hour box 2 encompasses the period from 1:00 am to 2:00 a.m. on the first day of the month, etc.

Time Overlap. When assigning footprints to regional hour boxes, it is possible that footprints from a given SSF input file may belong in regional hour boxes that had been opened during a previous processing run. To accommodate this, we use time overlap files, which we call leftover files.

Spatial Averaging. For Release 1, a simple arithmetic averaging technique will be used for most of the parameters. This technique cannot provide a meaningful average for some parameters, so different techniques, which are described in the Requirements Specification section of this document, have been developed for these parameters.

Key Footprint.   The key footprint of a region is that footprint whose center is closest to the center of the region. The key footprint is used to identify Julian date and time, Sun longitude and colatitude, solar zenith angle, spacecraft viewing zenith angle, and relative azimuth angle at the top-of-the-atmosphere for each regional hour box. These are quantities for which an arithmetic mean over the regional hour box would not be physically meaningful.

Metadata and Error Handling. Metadata and error handling will conform to the EOSDIS operating environment requirements, which are currently being defined. Metadata are discussed in the External Interface Requirements section of this document. Details regarding error handling have been deferred until more information on the operating environment is available. We assume that there will be a system-level set of error messages that will be invoked during processing. Fatal errors will result in a "graceful" halt to processing and diagnostic messages. Nonfatal errors will result in diagnostic messages to the operator/analyst and to the Quality Control (QC) reports.

Data Quality. For Release 1, all bad data are expected to have been flagged as bad or to have been eliminated from the input data products by the time that SFC processing takes place. We will make routine limit checks (reality checks) to ensure that the averaged data are within reasonable limits. Data that are outside these limits will be excluded from further processing, and a diagnostic message will be generated. Results of these limit checks will be included in the QC reports. The QC reports will also include data statistics, such as number of footprints in each regional hour box, and minimum and maximum values of averaged parameters.

Data Output. The gridding and spatial averaging functions are performed on an hourly basis, while the SFC archival product is a monthly product. A month of data will be accumulated and, before being passed on to the Compute Monthly and Regional TOA and SRB Averages, will be sorted by region and by local hour box. The final output product may be one file, or several files organized by latitudinal zone. This decision will be made in the design phase of this work, as more information on the operating environment becomes available.

3.0 Requirements Approach and Tradeoffs

Requirements for the Surface Gridding and Spatial Averaging Subsystem are based on information in the Algorithm Theoretical Basis Document (ATBD) for this Subsystem (Reference 2, Subsystem 9). For Release 1 of the CERES software, we assume that only data obtained while the instrument is operating in the Fixed Azimuth Plane Scan (FAPS) mode will be processed. However, since data obtained when the instrument is operating in the Rotating Azimuth Plane Scan (RAPS) mode may be included in the output product in future releases, the capability for handling such data has been built into these requirements. We assume that the Instrument Earth Scan (IES) quality flag that indicates instrument scan mode is included in the footprint data in the SSF input data product.

The following high level requirements have been identified for this Subsystem:

1. *Define the grid system to be used for CERES data processing*. For Release 1, the CERES grid system is a 1.25-degree equal area grid. An equal area grid reduces the distortion of the grid boxes at high latitudes. The grid system is only approximately equal area, as there must be an integral number of regions in each latitude zone.

2. *Assign each CERES footprint to the appropriate regional hour box*. For Release 1, CERES footprints will be assigned to regions based on the colatitude and longitude of the center of the footprint. If the center of the footprint falls within a region, the entire footprint is assigned to that region.

3. *Calculate spatial means and standard deviations for each regional hour box*. Spatial means and standard deviations will be calculated for each of the four data categories in the SFC data product: region data, radiative flux data, cloud data, and angular model scene type data. For Release 1, means and standard deviations of most of the parameters included in the SFC data product are calculated as simple arithmetic means and standard deviations, although weighted means will be calculated for the cloud properties.

4. *Produce the SFC output product and associated quality control reports*. The SFC output product is a CERES archival data product, and is defined in the CERES Data Products Catalog (Reference 1). The associated Quality Control (QC) report will be an internal data product. We assume that the metadata information required by EOSDIS is a subset of the QC information generated by this Subsystem during processing. The SFC output product will contain an entire month of data sorted by region and by local time within each region.

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.
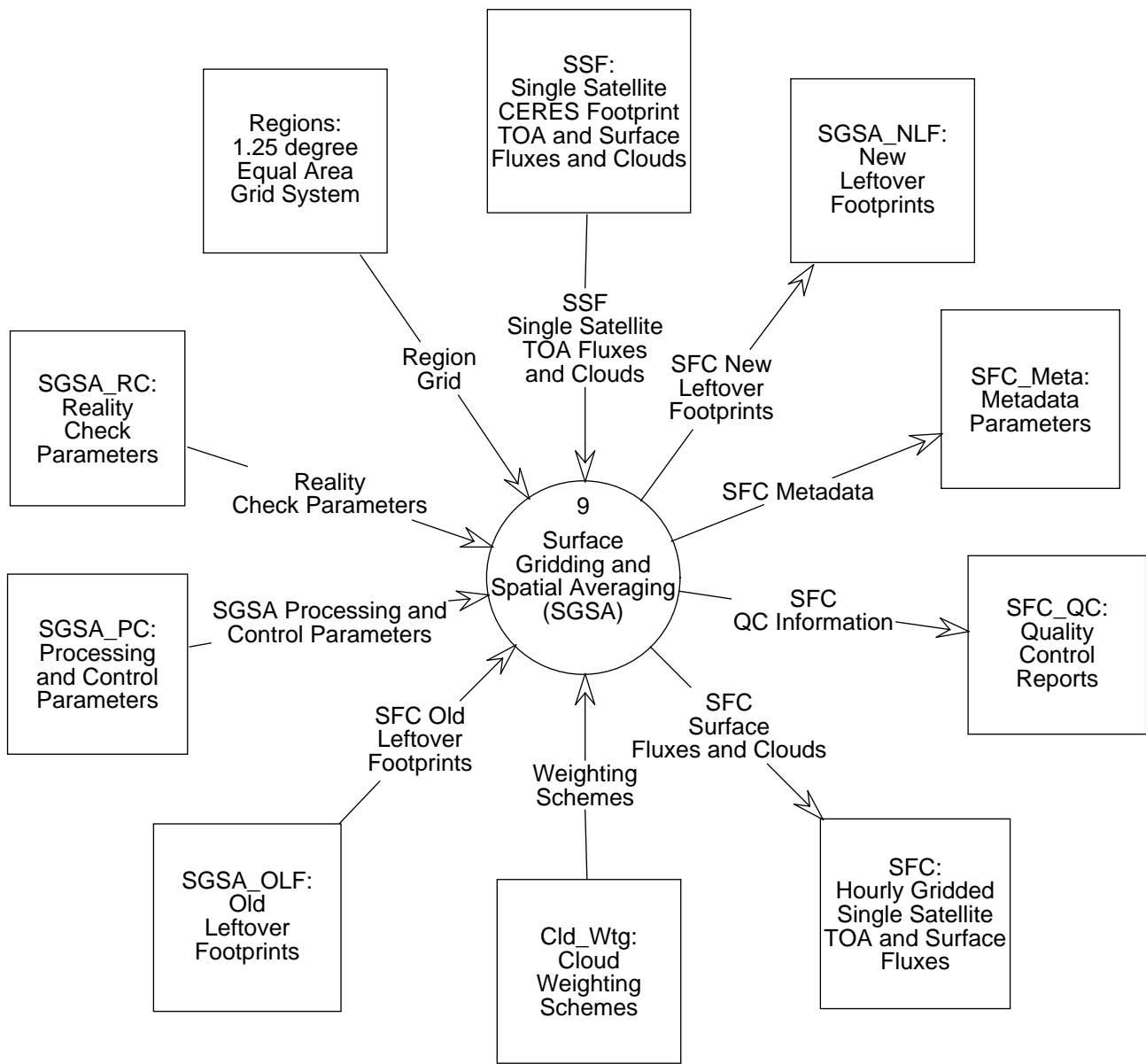
Figure 4-1. Context Diagram

4.1 Input Data Products

4.1.1 SSF Single Satellite TOA, Surface Flux, and Cloud Pixels

This flow represents the Single Satellite TOA, Surface Flux, and Cloud Pixels (SSF) archival data product generated by the Cloud Identification, Inversion, and Surface Processing Subsystem for CERES (see Reference 2, Subsystem 4.0). Each SSF covers a single hour swath from a single CERES instrument mounted on one satellite. The product has a product header and multiple

records of approximately 125 parameters or 315 elements for each footprint. Details of the SSF data product can be found in the CERES Data Management System Data Products Catalog (Reference 1).

For each CERES footprint, the SSF contains:

- CERES footprint geometry and CERES viewing angles
- CERES footprint radiance and flux (TOA and Surface)
- CERES footprint cloud statistics and imager viewing angles
- CERES footprint clear area statistics
- CERES footprint cloudy area statistics for each of four cloud height categories
    - Visible optical depth (mean and standard deviation)
    - Infrared emissivity (mean and standard deviation)
    - Liquid water path (mean and standard deviation)
    - Ice water path (mean and standard deviation)
    - Cloud top pressure (mean and standard deviation)
    - Cloud effective pressure (mean and standard deviation)
    - Cloud effective temperature (mean and standard deviation)
    - Cloud effective height (mean and standard deviation)
    - Cloud bottom pressure (mean and standard deviation)
    - Water particle radius (mean and standard deviation)
    - Ice particle radius (mean and standard deviation)
    - Particle phase (mean and standard deviation)
    - Vertical aspect ratio (mean and standard deviation)
    - Visible optical depth/IR emissivity (13 percentiles)
- CERES footprint cloud overlap conditions (11 conditions)

4.1.2 SGSA Processing and Control Parameters

This flow represents the set of information needed to run the Surface Gridding and Spatial Averaging Subsystem. Specific parameters include but are not limited to:

- Data date and time
- Instrument and spacecraft identification
- SSF file identification
- New Leftover File identification
- Old Leftover File identification

4.1.3 Region Grid

This flow represents the grid system or regions over which spatial averaging of CERES 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. One array 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 second array contains the region number of the first region in each of the 144 latitudinal zones.

4.1.4 Reality Check Parameters

This flow represents the parameter limits used for checking the values of averaged parameters in each region. The average value of each parameter needs to be within the maximum and minimum limits contained in the Reality Check Parameters data product. This data product also defines the minimum number of footprints that must be contained in a regional hour box in order for spatial averaging to be performed.

4.1.5 Weighting Schemes

This flow represents the five weighting schemes to be used in determining the weighted column-averaged cloud properties. The weighting schemes will be defined by the Science Team. The five weighting schemes are:

1. Weight by cloud radiative forcing effect on TOA and surface shortwave fluxes.
2. Weight by cloud radiative forcing effect on TOA longwave flux.
3. Weight by cloud radiative forcing effect on surface longwave flux.
4. Weight by liquid water path.
5. Weight by ice water path.

4.1.6 SFC Old Leftover Footprints

This flow represents regions that contain footprints from a previously processed SSF data product, but that have not yet been spatially averaged because footprints from the current SSF input data product may be assigned to these regions.

4.2 Output Data Products

4.2.1 SFC Surface Fluxes and Clouds

This flow represents the output SFC archival data product from the Surface Gridding and Spatial Averaging Subsystem (see Reference 2, Subsystem 9.0). The SFC archival product is a monthly product that contains hourly single satellite flux and cloud parameters that have been gridded and spatially averaged over 1.25-degree regions. This data product is sorted by region and by local time within each region. Details of the data product can be found in the CERES Data Management System Data Products Catalog (Reference 1).

The major categories of data output on the SFC are:

- Region parameters
- Radiative flux parameters for clear- and total-sky at TOA and surface
- Weighted column-averaged cloud properties
- Angular model scene type parameters

4.2.2 SFC QC Information

This flow represents the quality control reports produced by the Surface Gridding and Spatial Averaging Subsystem. Specific information provided in these reports includes but is not limited to:

- Spacecraft and instrument identification
- Data date and time
- Processing date and time
- Number of CERES footprints processed
- Number of regions processed
- Number of new leftover regions processed
- Number of old leftover regions processed
- Statistical data for each region, including minimum, maximum, mean, and standard deviation of selected parameters, and number of footprints in each region
- Diagnostic messages indicating any unexpected or unusual conditions occurring during processing

4.2.3 SFC Metadata

This flow represents the metadata that describes the SFC archival data product. The metadata shall conform to EOSDIS requirements and standards, which are currently being defined. Examples of metadata include:

- Product name and description

- Product type
- Platform and instrument identification
- Instrument operating mode
- Processing date, location
- Spatial extent of data product
- Temporal extent of data product

4.2.4 SFC New Leftover Footprints

This flow represents regions that have footprints in them from the currently processed SSF data product, but that are not yet ready to be spatially averaged because footprints from the next SSF data product may also be included in these regions.

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

For Release 1, this Subsystem will operate only in the normal processing mode, and only FAPS data will be processed. All valid data will be gridded, and spatial averages will be calculated for all parameters. The SFC archival product will be produced on a monthly basis.

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 p-specs will be used to define the testing requirements for the Subsystem and will be documented in a subsystem Test Plan and Procedures document.

5.2.1 Input Single Satellite TOA Fluxes and Clouds for one hour - Process 9.1

Input Data Flows
> SGSA Processing and Control Parameters
> SSF Single Satellite TOA Fluxes and Clouds
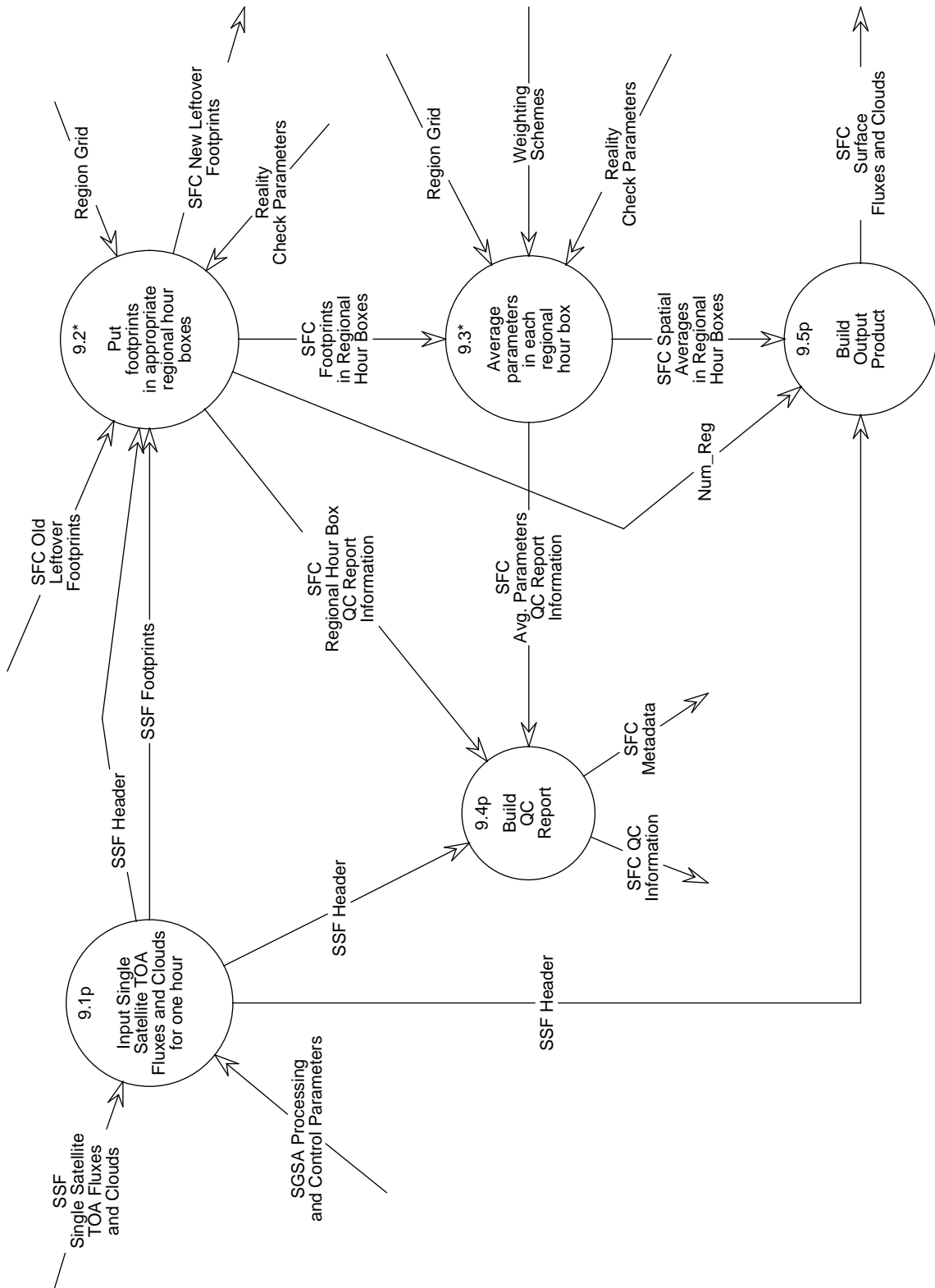
Output Data Flows
> SSF Footprints
> SSF Header

Figure 5-1. Data Flow Diagram for Level 0

Process Specification (Figure 5-1):

[1] This process shall read and validate the SGSA Processing and Control Parameters.

[2] This process shall access and read the SSF input data. If the required SSF data cannot be accessed, this process shall generate an error message for the operator/analyst and shall stop processing.

[3] This process shall verify that the header information, which includes date, time, spacecraft, and instrument identification, of the input SSF file matches that specified by the SGSA Processing and Control Parameters. If this information does not match, this process shall generate an error message for the operator/analyst and shall stop processing.

[4] If this information does match, processing shall continue. The header information shall be passed to Process 9.2, Put footprints in appropriate regional hour boxes, Process 9.4, Build QC Report, and Process 9.5, Build Output Product. The remainder of the parameters in the SSF file shall be passed to Process 9.2, Put footprints in appropriate regional hour boxes.

5.2.2 Put footprints in appropriate regional hour boxes - Process 9.2

Input Data Flows
>   Reality Check Parameters
>   Region Grid
>   SFC Old Leftover Footprints
>   SSF Footprints
>   SSF Header

Output Data Flows
>   Num Reg
>   SFC Footprints in Regional Hour Boxes
>   SFC New Leftover Footprints
>   SFC Regional Hour Box QC Report Information

Process Description (Figure 5-1):

This process performs the gridding function of the Atmospheric Gridding and Spatial Averaging Subsystem. The assignment of CERES footprints to regions is based on the colatitude and longitude of the CERES footprint field of view at the top of the atmosphere. This process also assigns hour box numbers to each footprint.   A decomposition of this gridding process is shown in Figure 5-2.

Figure 5-2. Data Flow Diagram for Put footprints in appropriate regional hour boxes

5.2.2.1 Input Leftover Footprints - Process 9.2.1

Input Data Flows
SFC Old Leftover Footprints
SSF Header

Output Data Flows
SSF Footprints in Regional Hour Boxes

Process Specification (Figure 5-2):

[5] This process shall verify the availability of the Old Leftover Footprints input file. If the required input file is not available, this process shall generate a diagnostic message, and subsystem processing shall continue with Process 9.2.2, Determine Region and Hour Box Numbers. If the Old Leftover Footprints input file is available, this process shall access the input file and read the header.

[6] This process shall validate the Leftover input file header information, which includes date, time, spacecraft, and instrument identification.   If the header information is not valid, this process shall generate an error message and shall terminate processing.

[7] If the header is valid, this process shall read each leftover footprint in the Old Leftover Footprints input file. This process shall pass the footprints to Process 9.2.3, Open/Close Regional Hour Boxes.

5.2.2.2 Determine Region and Hour Box Numbers - Process 9.2.2

Input Data Flows
Reality Check Parameters
Region Grid
SSF Footprints
Scan Mode

Output Data Flows
SSF Footprints in Regional Hour Boxes

Process Specification (Figure 5-2):

[8] This process shall use the grid definition from Regions to determine the region number corresponding to the center of each footprint read from SSF.   The center of the footprint is defined by the surface colatitude and longitude as calculated by CERES Subsystem 1, Geolocate and Calibrate (Reference 2, Subsystem 1.0). We note a fundamental error in these computations: The footprints overlap, so that data are repeated. The subsets represented by the footprints are not mutually exclusive. Also, they overlap the boundaries of the regional hour box.

[9] This process shall determine the local and GMT hour box numbers of each footprint based upon the Julian date and time of the footprint. Identification of regional hour boxes will be by local hour box number.

[10] This process shall pass the footprint with the region number and hour box number on to Process 9.2.3, Open/Close Regional Hour Boxes.

5.2.2.3 Open/Close Regional Hour Boxes - Process 9.2.3

Input Data Flows
> Num Footprint Min
> SSF Footprints in Regional Hour Boxes

Output Data Flows
> Num Reg
> SFC Regional Hour Box QC Report Information
> SSF Footprints in Regional Hour Boxes

Process Specification (Figure 5-2):

[11] This process shall open and close the regional hour boxes. To open a regional hour box means to determine the first time that a footprint is assigned to that regional hour box. To close a regional hour box means to determine when no more footprints can be assigned to that regional hour box.

[12] This process shall check the region and hour box numbers of each CERES footprint to determine which regional hour box each footprint belongs in, and to open the box if necessary.

[13] This process shall close each regional hour box when all footprints belonging in the box have been processed. Once a regional hour box is closed, all footprints for that box will be passed on to Process 9.3, Average Parameters in Each Regional Hour Box. If the total number of footprints in a regional hour box is less than a specified minimum (to be determined by the Science Team), no spatial averaging will be done for that regional hour box, and a diagnostic message will be sent to process 9.4, Build QC Report.

[14] This process shall pass on all regional hour boxes that remain open after all data have been processed to Process 9.2.4, Output Leftover Footprints.

[15] This process shall accumulate quality control statistics, including the total number of footprints processed, number of old and new leftover footprints, the number of regional hour boxes opened, and number of regional hour boxes closed. These statistics shall be passed on to Process 9.4, Build QC Report.

5.2.2.4 Output Leftover Footprints - Process 9.2.4

Input Data Flows
> SSF Footprints in Regional Hour Boxes
> SSF Header

Output Data Flows
> SFC New Leftover Footprints

Process Specification (Figure 5-2):

[16] This process shall create a New Leftover Footprints output file for the particular spacecraft, date, hour, and instrument identification. This process shall output the footprints for all regions that are currently open.

5.2.3 Average parameters in each regional hour box - Process 9.3

Input Data Flows
> Reality Check Parameters
> Region Grid
> SFC Footprints in Regional Hour Boxes
> Weighting Schemes

Output Data Flows
> SFC Avg. Parameters QC Report Information
> SFC Spatial Averages in Regional Hour Boxes

Process Description (Figure 5-1):

This process performs the spatial averaging function of the Atmospheric Gridding and Spatial Averaging Subsystem. Averages are calculated for each of four categories of data: region data, radiative flux data, cloud data, and angular model scene type data. A decomposition of the spatial averaging process is shown in Figure 5-3.

5.2.3.1 Average Region Parameters - Process 9.3.1

Input Data Flows
> Footprint Geometry
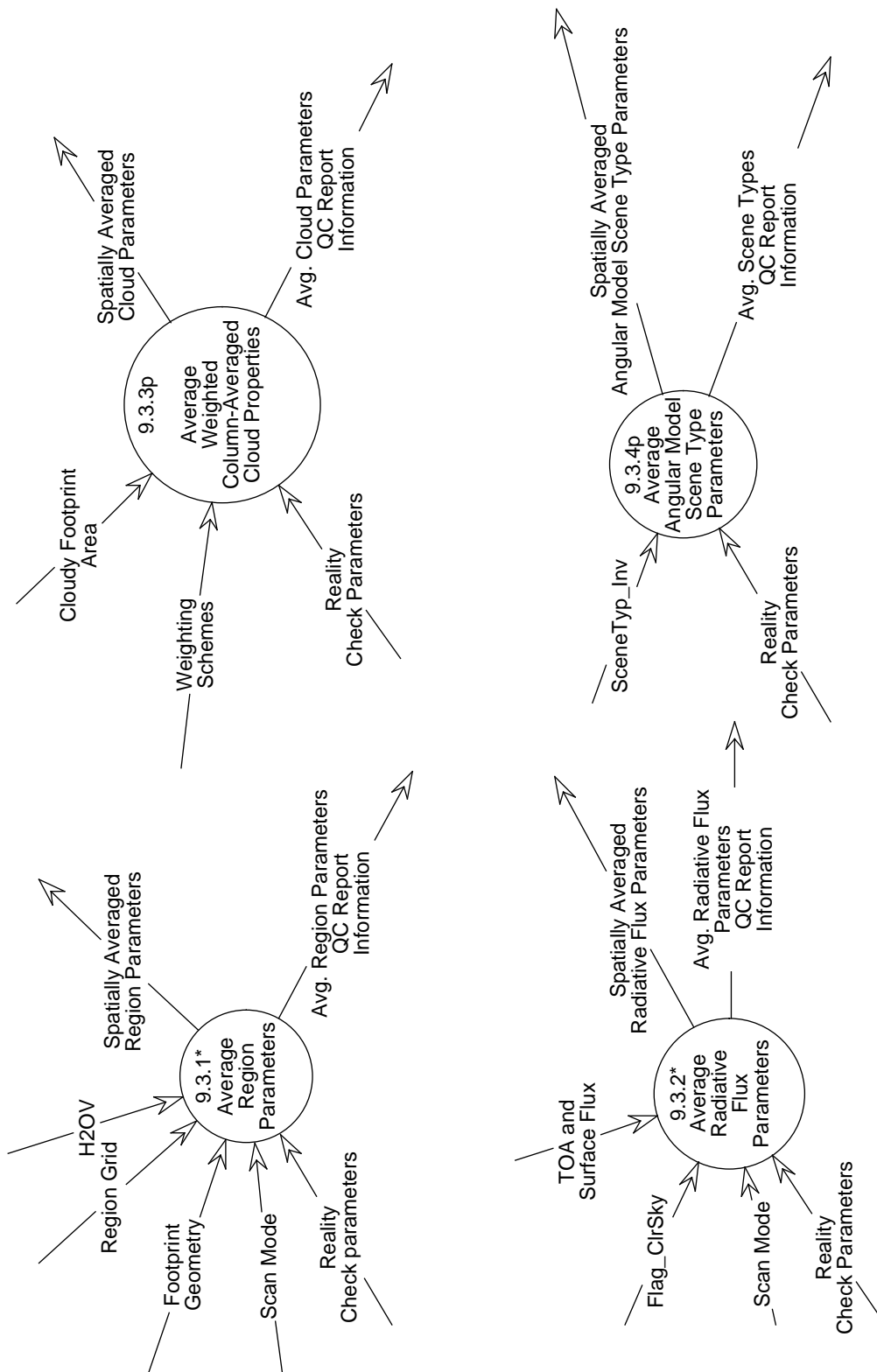> H2OV
> Reality Check parameters
> Region Grid
> Scan Mode

Figure 5-3. Data Flow Diagram for Average parameters in each regional hour box

Output Data Flows
> Avg. Region Parameters QC Report Information
> Spatially Averaged Region Parameters

Process Description (Figure 5-3):

Region parameters include region number, hour box number, number of CERES footprints in the regional hour box, Julian time, precipitable water, fractional geographic scene type, and geometry parameters. The region number combined with the hour box number identify the regional hour box. This process will determine the appropriate values of these region parameters to be assigned to each regional hour box. Different methods will be used for different types of parameters.

A decomposition of this averaging process is shown in Figure 5-4.

5.2.3.1.1 Determine Key Footprint - Process 9.3.1.1

Input Data Flows
> CERES Viewing Angles
> Region Grid
> Scan Mode
> Time and Position

Output Data Flows
> Key Footprint Parameters
> Key Footprint QC Report Information

Process Specification (Figure 5-4):

[17] This process shall determine the key footprint of each regional hour box. Determination of a key footprint depends on the scan mode of the instrument. For data obtained during FAPS operation, the key footprint of a regional hour box is defined as that footprint whose optical axis is closest to the geographic center of that regional hour box.

[18] Time and geometry parameters of the key footprint in the regional hour box shall be designated in the time and geometry parameters of the regional hour box. Geometry parameters include Sun longitude and colatitude, solar zenith angle, spacecraft viewing zenith angle, and relative azimuth angle at TOA. The solar zenith angle may be calculated for each region based on the center of the region, rather than being assigned based on the key footprint. This will be decided by the CERES Science Team during the design phase of this Subsystem.

[19] This process shall pass the key footprint time and geometry parameters to Process 9.5, Build Output Product, and the QC Report information and to Process 9.4, Build QC Report.
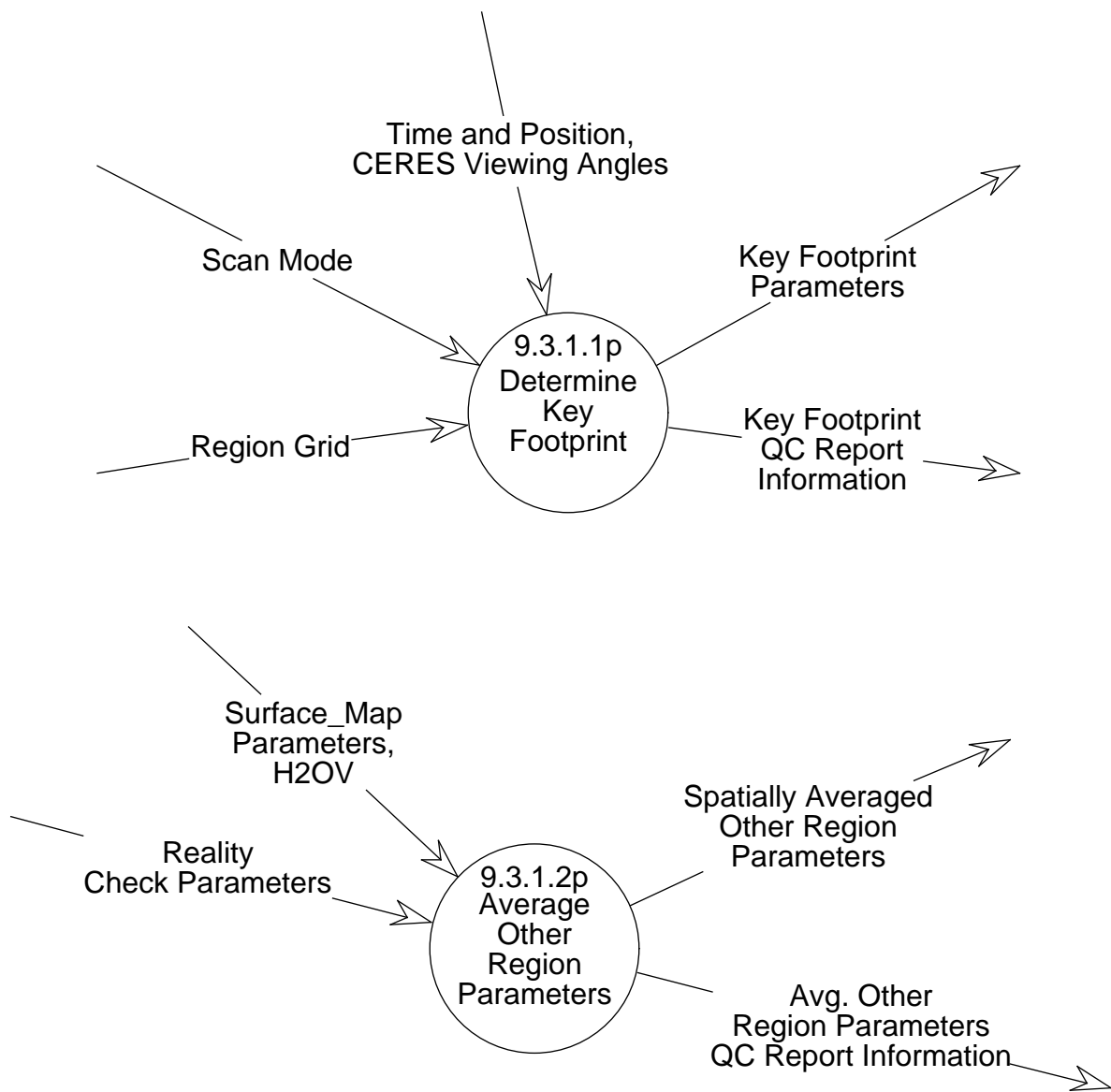
Figure 5-4. Data Flow Diagram for Average Region Parameters

5.2.3.1.2 Average Other Region Parameters - Process 9.3.1.2

Input Data Flows

      H2OV
      Reality Check Parameters
      Surface Map Parameters

Output Data Flows
Avg. Other Region Parameters QC Report Information
Spatially Averaged Other Region Parameters

Process Specification (Figure 5-4):

[20] This process shall calculate the arithmetic mean and standard deviation of precipitable water and of fractional geographic scene type for each regional hour box.

[21] This process shall execute a reality check on the average precipitable water and fractional geographic scene type parameters to ascertain that they are within specified limits.

[22] This process shall pass the spatially averaged parameters to Process 9.5, Build Output Product, and the QC report information to Process 9.4, Build QC Report.

5.2.3.2 Average Radiative Flux Parameters - Process 9.3.2

Input Data Flows
Flag ClrSky
Reality Check Parameters
Scan Mode
TOA and Surface Flux

Output Data Flows
Avg. Radiative Flux Parameters QC Report Information
Spatially Averaged Radiative Flux Parameters

Process Description (Figure 5-3):

This process calculates the spatial averages and standard deviations of total-sky and of clear-sky radiative flux parameters. For Release 1, simple arithmetic means and standard deviations will be calculated.   A decomposition of this averaging process is shown in Figure 5-5.

5.2.3.2.1 Calculate Total Sky Fluxes - Process 9.3.2.1

Input Data Flows
Flag ClrSky
Reality Check Parameters
Scan Mode
TOA and Surface Flux
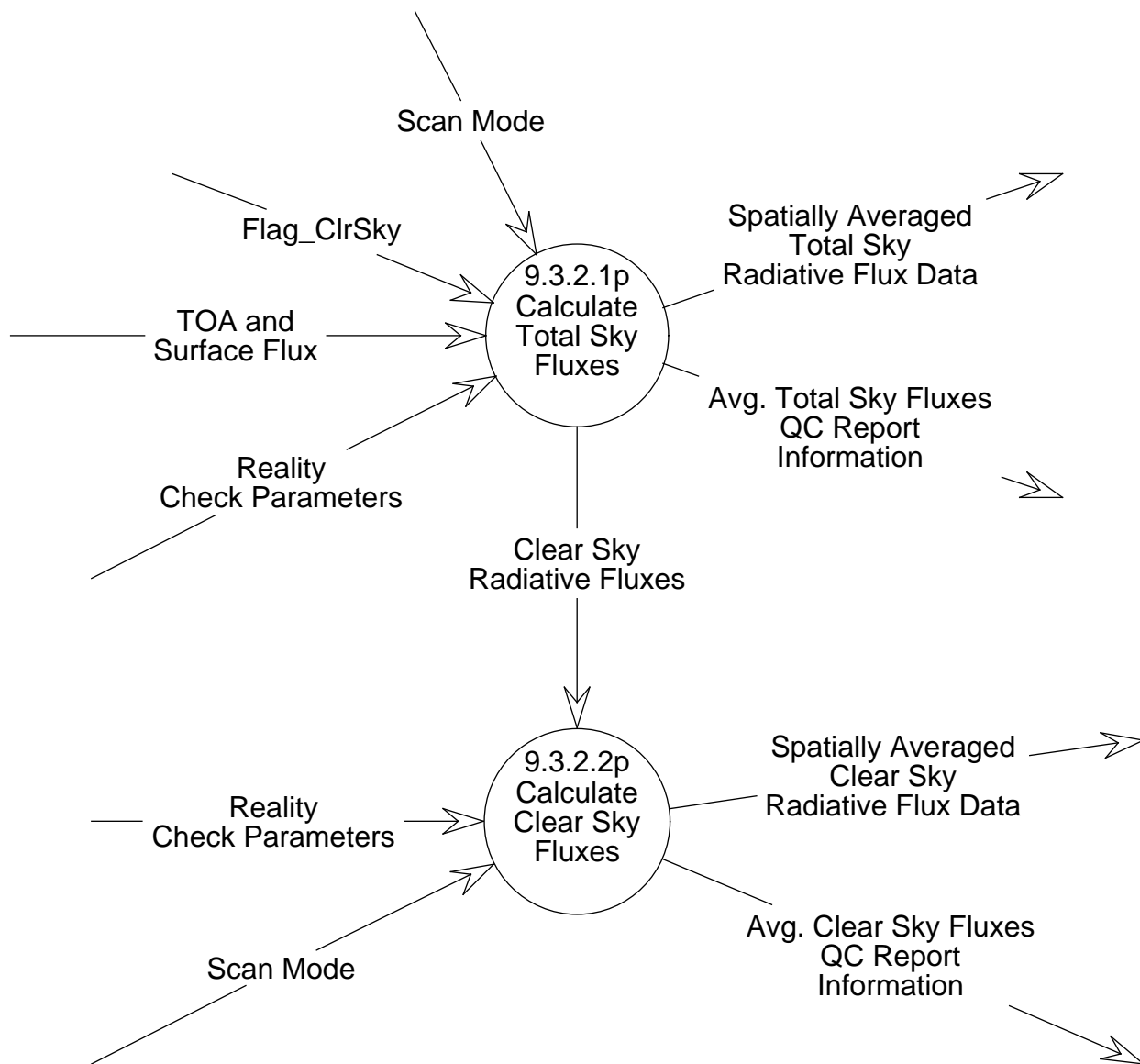
Figure 5-5. Data Flow Diagram for Average Radiative Flux Parameters

Output Data Flows

Avg. Total-Sky Fluxes QC Report Information
Clear-Sky Radiative Fluxes
Spatially Averaged Total-Sky Radiative Flux Data

Process Specification (Figure 5-5):

[23] This process shall sort clear-sky footprints from total-sky footprints using the footprint clear-sky/total-sky flag in the SSF data product. The clear-sky footprints shall be used in the calculation of total-sky averages, and shall also be passed to Process 9.3.2.2, Calculate Clear-Sky Fluxes.

[24] This process shall calculate means and standard deviations of radiative flux parameters for total-sky footprints. For Release 1, the mean value $\tilde{x}$ of parameter x in a given regional hour box is defined by:

$$\tilde{x} = \left(\sum_{i}^{N} x_i \right) / N \tag{1}$$

where N is the number of footprints in the regional hour box for which the average is being computed, and x_i is the value of parameter x in footprint i.

The standard deviation s is defined by:

$$s = \sqrt{(N-1)^{-1} \left[\sum_{i=1}^{N} x_i^2 - N\tilde{x}^2 \right]} \tag{2}$$

where N is the number of footprints averaged in the regional hour box, x_i is the value of parameter x in footprint i, and $\tilde{x}$ is the mean value of parameter x in the regional hour box.

The total-sky radiative flux parameters to be averaged include:

1. SW upward flux at TOA
2. LW upward flux at TOA
3. LW window upward flux at TOA
4. SW downward fluxes at surface
5.   SW upward fluxes at surface
6. LW downward fluxes at surface
7.   LW upward fluxes at surface

Details about these parameters can be found in the Data Products Catalog (Reference 1).

[25] This process shall perform a reality check on each of the averaged parameters to ascertain that they are within specified limits, and shall pass the results of the these checks as QC report information to the Process 9.4, Build QC Report.

[26] This process shall pass the spatially averaged parameters to Process 9.5, Build Output Product, and the QC report information to Process 9.5, Build QC Report.

5.2.3.2.2 Calculate Clear Sky Fluxes - Process 9.3.2.2

Input Data Flows
>   Clear Sky Radiative Fluxes
>   Reality Check Parameters
>   Scan Mode

Output Data Flows
>   Avg. Clear Sky Fluxes QC Report Information
>   Spatially Averaged Clear Sky Radiative Flux Data

Process Specification (Figure 5-5):

[27] This process shall calculate means and standard deviations of radiative flux parameters for clear-sky footprints using equations (1) and (2) from above.

The clear-sky radiative flux parameters to be averaged include:

1. SW upward flux at TOA
2. LW upward flux at TOA
3. LW window upward flux at TOA
4. SW downward fluxes at surface
5. SW upward fluxes at surface
6. LW downward fluxes at surface
7. LW upward fluxes at surface

Details about these parameters can be found in the Data Products Catalog (Reference 1).

[28] This process shall perform a reality check on each of the averaged parameters to ascertain that they are within specified limits, and shall pass the results of the these checks as QC report information to Process 9.4, Build QC Report.

[29] This process shall pass the spatially averaged parameters to Process 9.5, Build Output Product, and the QC report information to Process 9.4, Build QC Report.

5.2.3.3 Average Weighted Column-Averaged Cloud Properties - Process 9.3.3

Input Data Flows
>   Cloudy Footprint Area
>   Reality Check Parameters
>   Weighting Schemes

Output Data Flows
>   Avg. Cloud Parameters QC Report Information
>   Spatially Averaged Cloud Parameters

Process Specification (Figure 5-3):

This process is being held in abeyance pending input from the cloud working group.

[30] This process shall calculate the means and standard deviations of weighted column-averaged cloud properties for each of five different weighting schemes.

The weighting schemes are:

1. Weight by cloud radiative forcing effect on TOA and surface shortwave fluxes.
2. Weight by cloud radiative forcing effect on TOA longwave flux.
3. Weight by cloud radiative forcing effect on surface longwave flux.
4. Weight by liquid water path.
5. Weight by ice water path.

The specific equations to be used for these weighting schemes have not yet been finalized.

The cloud properties to be averaged include:

1. Effective pressure
2. Effective temperature
3. Effective altitude
4. Cloud top pressure
5. Cloud bottom pressure
6. Cloud particle phase
7. Liquid water path
8. Ice water path
9. Liquid particle radius
10. Ice particle radius
11. Visible optical depth
12. Infrared emissivity
13. Vertical aspect ratio

[31] This process shall perform a reality check on each of the averaged parameters to ascertain that they are within specified limits and shall pass the results of these checks as QC report information to Process 9.4, Build QC Report.

[32] This process shall pass the spatially averaged parameters to Process 9.5, Build Output Product, and the QC report information to Process 9.4, Build QC Report.

5.2.3.4 Average Angular Model Scene Type Parameters - Process 9.3.4

Input Data Flows
      Reality Check Parameters
      SceneTyp Inv

Output Data Flows
      Avg. Scene Types QC Report Information
      Spatially Averaged Angular Model Scene Type Parameters

Process Specification (Figure 5-3):

Each CERES footprint will be categorized according to angular model scene type. For Release 1, we will use the twelve ERBE scene types. Categorization is based on the underlying surface (ocean, land, snow, desert, or coastal), and on the total cloud fraction (clear, partly cloudy, mostly cloudy, or overcast) derived for the CERES footprint.   The twelve angular model scene types are

1. Ocean
2. Land
3. Snow
4. Desert
5. Land/Ocean (Coastal)
6. Partly cloudy over ocean
7. Partly cloudy over land
8. Partly cloudy over land/ocean
9. Mostly cloudy over ocean
10. Mostly cloudy over land
11. Mostly cloudy over land/ocean
12. Overcast

[33] This process shall calculate, for each scene type within each regional hour box:

1. Fractional area coverage
2. Mean and standard deviation of albedo
3. Mean of incident solar flux
4. Mean and standard deviation of longwave flux

[34] This process shall perform a reality check on each of the averaged parameters to ascertain that they are within specified limits, and shall pass the results of the these checks as QC report information to Process 9.4, Build QC Report.

[35] This process shall pass the spatially averaged parameters to Process 9.5, Build Output Product, and the QC report information to Process 9.4, Build QC Report.

5.2.4 Build QC Report - Process 9.4

Input Data Flows
    SFC Avg. Parameters QC Report Information
    SFC Regional Hour Box QC Report Information
    SSF Header

Output Data Flows
    SFC Metadata
    SFC QC Information

Process Specification Figure 5-1):

[36] This process shall build and output the Quality Control (QC) report for each hourly SFC product.

The QC report shall include such information as:

- spacecraft and instrument identification
- data date and time
- process date and time
- number of input and output records processed
- number of regions processed and averaged
- number of CERES footprints processed
- statistical data for selected parameters in each region, including minimum, maximum, mean, standard deviation and number of footprints
- diagnostic messages indicating any unexpected or unusual conditions discovered during processing

[37] This process shall output the appropriate SFC metadata parameters as required by EOSDIS.

5.2.5 Build Output Product - Process 9.5

Input Data Flows
    Num Reg
    SFC Spatial Averages in Regional Hour Boxes
    SSF Header

Output Data Flows
    SFC Surface Fluxes and Clouds

Process Specification (Figure 5-1):

[38] This process shall create and build the SFC archival product from header information and the spatially averaged regional hour box data for each month. The monthly output product will be sorted by region and by local hour box number within each region.

The averaged regional hour box data includes:

- Region parameters
- Radiative flux parameters
    - Total-sky fluxes
    - Clear-sky fluxes
- Weighted column-averaged cloud properties
- Angular model scene type parameters
- Surface-only parameters

5.3 Design Goals and Constraints

The Release 1 design of the Surface Gridding and Spatial Averaging software will address only data obtained when the CERES instrument is operating in a fixed azimuth scan mode. We intend the design to be flexible enough that subsequent releases can address data obtained when the instrument is operating in rotating azimuth plane scan mode, with minimum impact to the design.

We plan to use an object oriented design approach implemented in the FORTRAN 90 programming language in a UNIX environment.

The design of this Subsystem will be constrained by the EOSDIS PGS operating environment and the StP Toolkit, which are currently under development.

5.4 Resource Use

The estimated size of the SFC hourly product is 2.1 MB. As the definition of the SFC data product matures, this size estimate may change.   We anticipate a monthly size of 1563 MB.

The CPU processing load required has been estimated based on the ERBE Daily Database processing requirements (see Reference 2, Volume 0).   We estimate that 1.3 hours of Sun SPARC 2 CPU processing time is required to process 1-hour of data through the Surface Gridding and Spatial Averaging Subsystem. Assuming 768 hourly runs per month, 998 hours of CPU processing time will be required to run 1-month of data through this Subsystem.

References

1. CERES Data Management System Data Products Catalog, Release 1, Version 1. August 1994.

2. CERES Algorithm Theoretical Basis Documents, Release 1.1, April 1994.

Abbreviations, Acronyms, and Symbols

AGSA	Atmospheric Gridding and Spatial Averaging
ATBD	Algorithm Theoretical Basis Document
BRIE	Best Regional Integral Estimator
CERES	Clouds and the Earth's Radiant Energy System
CLS	Constrained Least Squares
CPU	Central Processing Unit
CRS	Single Satellite CERES Footprint, Radiative Fluxes and Clouds (formerly Cloud Radiative Swath) (CERES Archival Data Product)
DAAC	Distributed Active Archive Center
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
FAPS	Fixed Azimuth Plane Scan
FSW	Hourly Gridded Single Satellite Fluxes and Clouds (formerly Flux and Clouds Regional Swath) (CERES Archival Data Product)
GMT	Greenwich Mean Time
IES	Instrument Earth Scan
INT	Integer
IR	Infrared
ISCCP	International Satellite Cloud Climatology Project
IWP	Ice Water Path
LW	Longwave
LWP	Liquid Water Path
MB	Megabyte
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
PW	Precipitable Water
PGS	Product Generation System
QC	Quality Control
RAPS	Rotating Azimuth Plane Scan
SARB	Surface and Atmospheric Radiation Budget Working Group
SFC	Surface Flux and Clouds (CERES Archival Data Product)
SGSA	Surface Gridding and Spatial Averaging
SRD	Software Requirements Document
SSF	Single Satellite Flux (CERES Archival Data Product)
SW	Shortwave
TISA	Time Interpolation and Spatial Averaging
TOA	Top-of-Atmosphere
TRMM	Tropical Rainfall Measuring Mission
UT	Universal Time
Win	Window