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

Data Management System

Software Requirements Document

Atmospheric Gridding and Spatial Averaging
(Subsystem 6.0)

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 Atmospheric Gridding and Spatial Averaging (AGSA) Subsystem (Subsystem 6.0). The intended audience for this document is the CERES Data Management Team and the CERES Subsystem 6.0 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 we call 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.

Revisions to this Software Requirements Document (SRD) will be incorporated into Release 2, 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

- 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 Atmospheric 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 CERES Footprint, Radiative Fluxes, and Clouds (formerly Cloud Radiation Swath) (CRS) 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 Fluxes and Clouds (formerly Flux and Clouds Regional Swath) (FSW) data product, which contains radiative fluxes and cloud properties spatially averaged by regional hour box. Details of CRS and FSW 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), the surface, and designated atmospheric levels. 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 Atmospheric Gridding and Spatial Averaging Subsystem:

Grid System.   This Subsystem defines the grid system that is used in CERES data processing. Other CERES subsystems (for example, the Regrid Humidity and Temperature Fields Subsystem) will use this same grid system. 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 Julian 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. Regional hour box 1 encompasses the period from midnight to 1:00 am on the first day of the month, regional hour box 2 encompasses the period from 1:00 am to 2:00 am 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 CRS 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 will not provide a meaningful average for some parameters, so different averaging techniques, which are described in the Requirements Specification Section of this document, have been developed for these parameters. These parameters include certain region data parameters, such as Julian time and solar geometry; the optical depth histogram; and the direct/diffuse flux ratio.

Key Footprint. The key footprint of a region is that footprint whose center is closest to the center of the region. We use the concept of a key footprint 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. All bad data are expected to have been flagged as bad or eliminated from the input data products by the time that FSW processing takes place. We will check for data quality flags, and we 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. Our current understanding is that the Merge Satellite, Time Interpolate, Compute Fluxes Subsystem (Subsystem 7.0) will not begin processing until an entire month of FSW data is available. Hence, the hourly FSW archival data products need to be stored in a data repository until an entire month of data is available to be passed on to the next processing subsystem.

3.0 Requirements Approach and Tradeoffs

Requirements for the Atmospheric Gridding and Spatial Averaging Subsystem are based on information in the Algorithm Theoretical Basis Document (ATBD) for this Subsystem (Reference 2, Subsystem 6.0). 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 CRS 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 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 the 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 six data categories in the FSW data product: region data, radiative flux data, cloud data, angular model scene type data, surface-only data, and adjustment parameter data. For Release 1, means and standard deviations of most of the parameters included in the FSW data product are calculated as simple arithmetic means and standard deviations, although weighted means will be calculated for some of the cloud properties.   Some parameters, especially some of the region data parameters, the optical depth/infrared (IR) emissivity histogram, and the direct/ diffuse flux ratio, require special averaging methods. Work is in progress to evaluate techniques for producing spatial means and standard deviations that are more mathematically rigorous and more physically meaningful. These techniques include the Constrained Least Squares (CLS) technique and the Best Regional Integral Estimator (BRIE) technique (References 2, 3).

4. *Produce the FSW output product and associated quality control reports.* The FSW output product is a CERES archival data product; it is defined in the CERES Data Products Catalog (Reference 1). The associated Quality Control (QC) report is 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.

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.
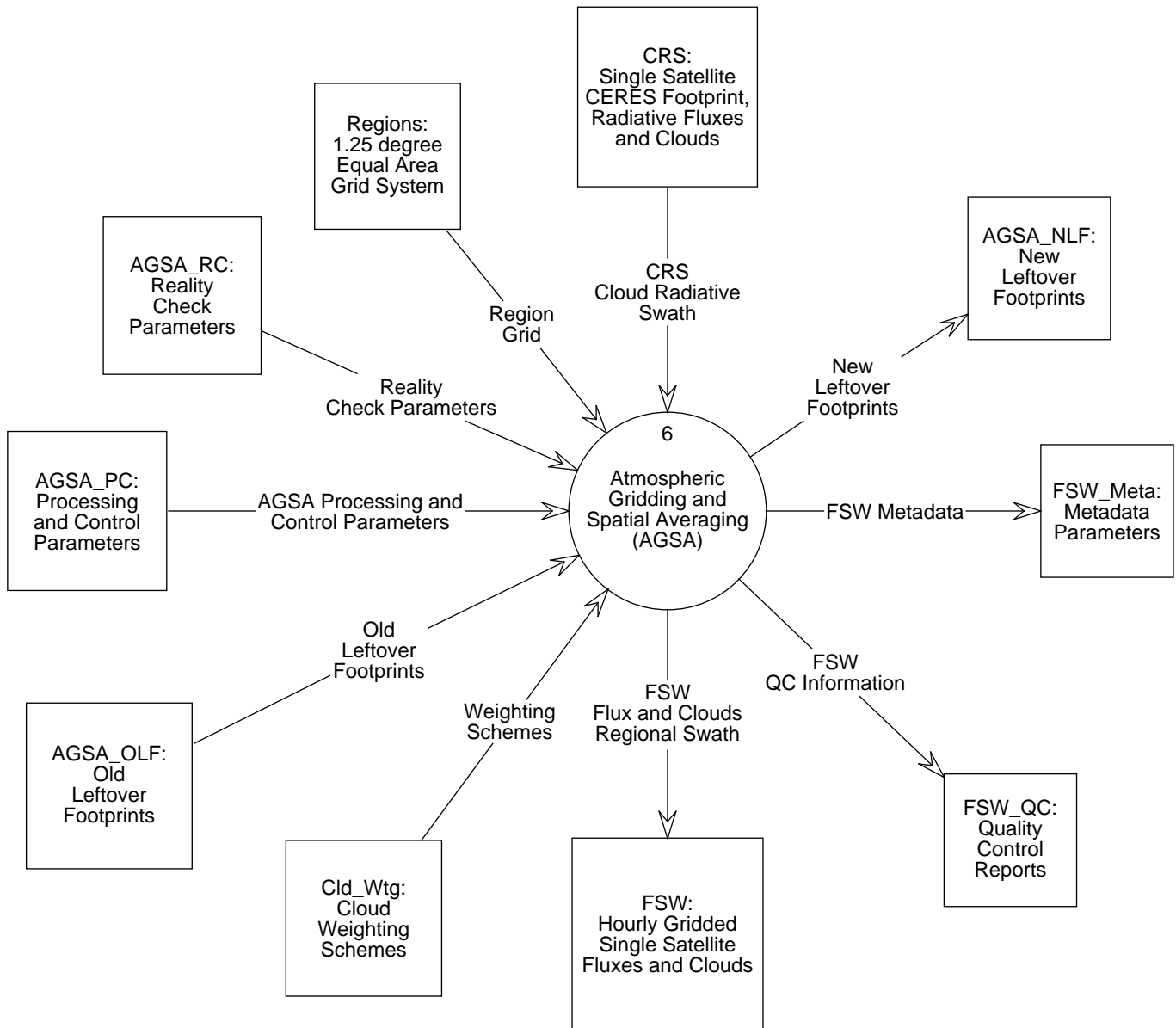
Figure 4-1. Context Diagram

4.1 Input Data Sources

4.1.1 CRS Cloud Radiative Swath

This flow represents the CRS archival data product generated by the CERES Compute Surface and Atmospheric Radiative Fluxes Subsystem (see Subsystem 5.0, Reference 2). This Subsystem is also known as the Footprint Surface and Atmospheric Radiation Budget (SARB) Subsystem. Each CRS file contains longwave (LW) and shortwave (SW) radiative fluxes for the surface, internal atmosphere, and top-of-the-atmosphere (TOA) for each CERES footprint. The CRS contains data for a one-hour, single satellite swath (8-12 percent of the Earth). This file is organized as a header record followed by a series of records, each of which represents a single CERES footprint. Details of the CRS data product can be found in the CERES Data Management System Data Products Catalog (Reference 1).

For each CERES footprint, the CRS contains:

- Time and location data
- CERES observed TOA data
- Full footprint data
- Full footprint algorithm flags
- Footprint clear-sky properties
- Cloud category properties for up to four (low, lower middle, upper middle, and high) cloud layers
- Cloud overlap conditions: clear (CL), low (L), lower middle (LM), upper middle (UM), high (H), H/UM, H/LM, H/L, UM/LM, UM/L, and LM/L
- Atmospheric flux profile for both clear-sky and total-sky at the surface, 500 hPa, the tropopause, and TOA
- Flux adjustments (tuned-untuned) for clear-sky and total-sky at the surface and TOA
- Surface-only data
- Adjustment parameters for clear-sky
- Adjustment parameters for L, LM, UM, and H cloud layers

4.1.2 AGSA Processing and Control Parameters

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

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

4.1.3 Reality Check Parameters

This flow represents the parameter limits used for checking the values of averaged parameters in each region and for checking the validity of the hour box number and region number. 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.

4.1.4 Old Leftover Footprints

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

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 CERES 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 Region Grid

This flow represents the grid system or regions over which spatial averaging of FSW 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 east-ward 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.

4.2 Output Data Products

4.2.1 FSW Flux and Clouds Regional Swath

This flow represents the output FSW archival data product from the Atmospheric Gridding and Spatial Averaging Subsystem (see Subsystem 6.0, Reference 2). This data product contains hourly single satellite flux and cloud parameters averaged over 1.25-degree regions. Each FSW covers a single hour swath from a single CERES instrument mounted on one satellite. The product contains a product header and multiple records; each record contains spatially averaged data for an individual regional hour box. 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 FSW are:

- Region parameters
- Total-sky radiative flux parameters at TOA, surface, and atmospheric levels
- Clear-sky radiative flux parameters at TOA, surface, and atmospheric levels
- Cloud overlap conditions
- Cloud category properties
- Column-averaged cloud properties
- Angular model scene type parameters
- Surface-only parameters
- Adjustment parameters

4.2.2 New Leftover Footprints

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

4.2.3 FSW QC Information

This flow represents the quality control reports associated with he FSW data product. 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

4.2.4 FSW Metadata

This flow represents the metadata that describes the FSW 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

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. All data will be gridded, and spatial averages will be calculated for all parameters.

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 (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 Cloud Radiation Swath for one hour - Process 6.1

Input Data Flows
> AGSA Processing and Control Parameters
> CRS Cloud Radiative Swath

Output Data Flows
> CRS Footprints
> CRS Header

Process Specification (Figure 5-1):

[1] This process shall read and validate the AGSA Processing and Control Parameters.
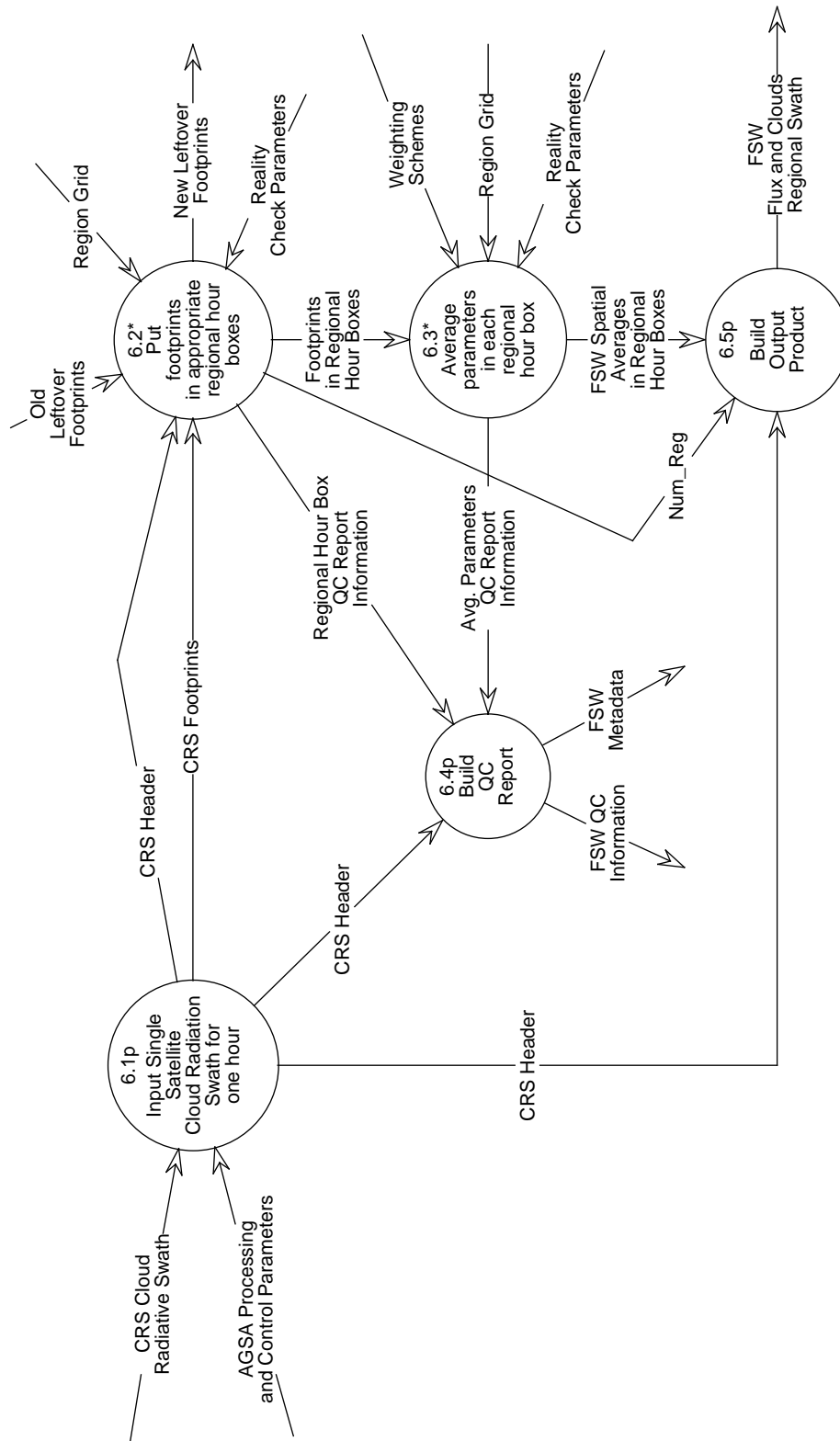
Figure 5-1. Data Flow Diagram for Level 0

[2] This process shall access and read the CRS input data. If the required CRS 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 CRS file matches that specified by the AGSA 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 AGSA Processing and Control Parameters, processing shall continue. The header information shall be passed to process 6.2, Put footprints in appropriate regional hour boxes; process 6.4, Build QC Report; and process 6.5, Build Output Product. The remainder of the parameters in the CRS file shall be passed to process 6.2, Put footprints in appropriate regional hour boxes.

5.2.2 Put footprints in appropriate regional hour boxes - Process 6.2

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

Output Data Flows
>   Footprints in Regional Hour Boxes
>   New Leftover Footprints
>   Num Reg
>   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.

The decomposition for this function 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 6.2.1

Input Data Flows
> CRS Header
> Old Leftover Footprints

Output Data Flows
> 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 6.2.2, 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 header information, which includes date, time, spacecraft, and instrument identification, of the Leftover Input File.   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 6.2.3, Open/Close Regional Hour Boxes.

5.2.2.2 Determine Region and Hour Box Numbers - Process 6.2.2

Input Data Flows
> CRS Footprints
> Reality Check Parameters
> Region Grid
> Scan Mode

Output Data Flows
> 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 CRS.   The center of the footprint is defined by the surface colatitude and longitude as calculated by CERES Subsystem 1.0, Geolocate and Calibrate (Subsystem 1.0, Reference 3). 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 hour box number of each footprint based upon the Julian date and time of the footprint.

[10] This process shall pass the footprint with the region number and hour box number on to Process 6.2.3, Open/Close Regional Hour Boxes.

5.2.2.3 Open/Close Regional Hour Boxes - Process 6.2.3

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

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

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 6.3, 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 CERES Science Team), no spatial averaging will be done for that regional hour box, and a diagnostic message will be sent to process 6.4, Build QC Report.

[14] This process shall pass on all regional hour boxes that remain open after all data have been processed to Process 6.2.4, 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 6.4, Build QC Report.

5.2.2.4 Output Leftover Footprints - Process 6.2.4

Input Data Flows
 CRS Header
 Footprints in Regional Hour Boxes

Output Data Flows
 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 6.3

Input Data Flows
 Footprints in Regional Hour Boxes
 Reality Check Parameters
 Region Grid

Output Data Flows
 Avg. Parameters QC Report Information
 FSW 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 six categories of data: region data, radiative flux data, cloud data, angular model scene type data, surface only data, and adjustment parameter data.

The decomposition for this function is shown in Figure 5-3.

5.2.3.1 Average Region Parameters - Process 6.3.1

Input Data Flows
 Precip H2O
 Reality Check parameters
 Region Grid
 SSF TIME AND LOCATION
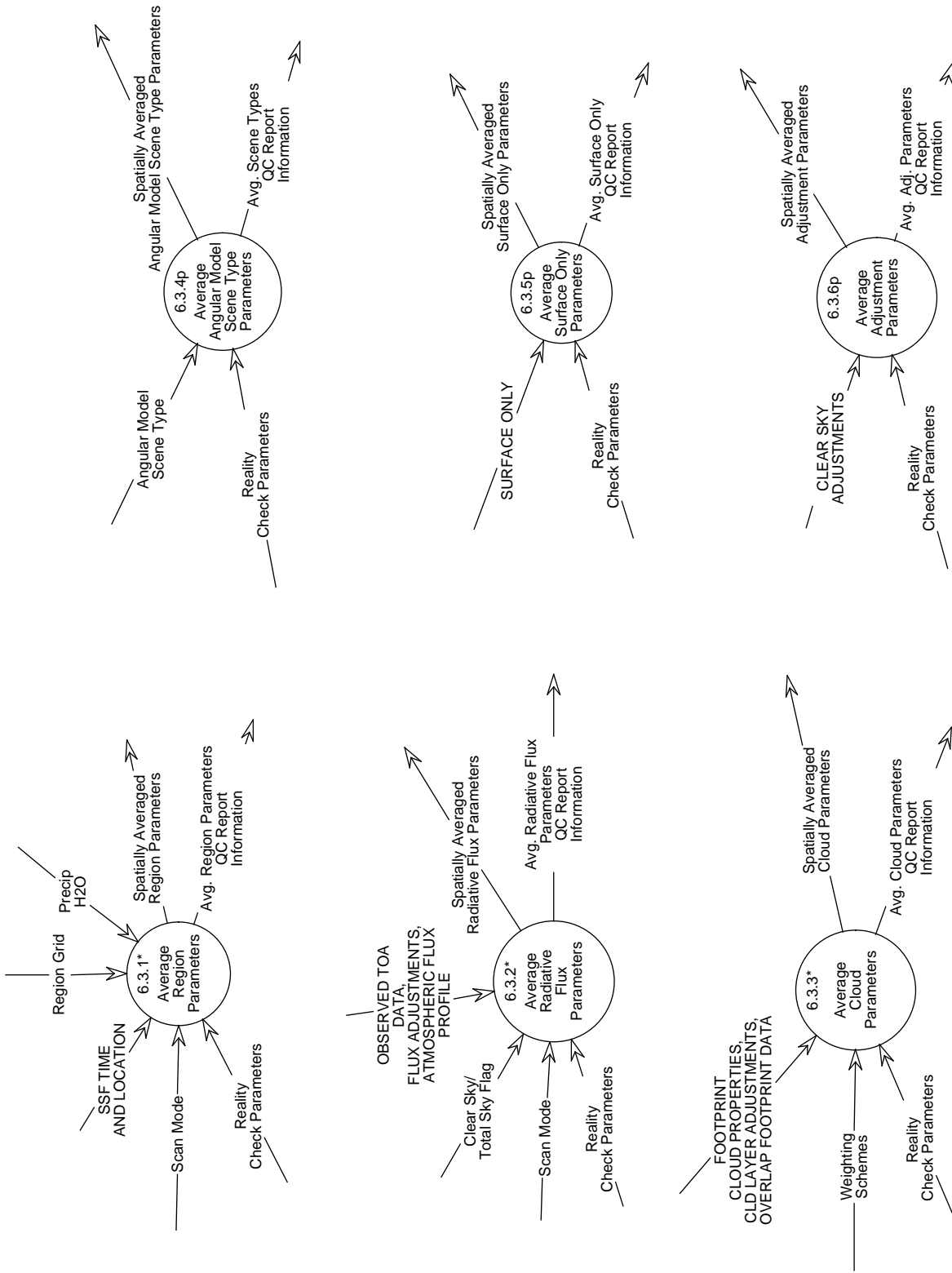 Scan Mode

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.

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

5.2.3.1.1 Determine Key Footprint - Process 6.3.1.1

Input Data Flows
       Region Grid
       SSF TIME AND LOCATION
       Scan Mode

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 Release 1, 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 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.

[19] This process shall pass the key footprint time and geometry parameters to Process 6.5, Build Output Product, and the QC Report information and to Process 6.4, Build QC Report.
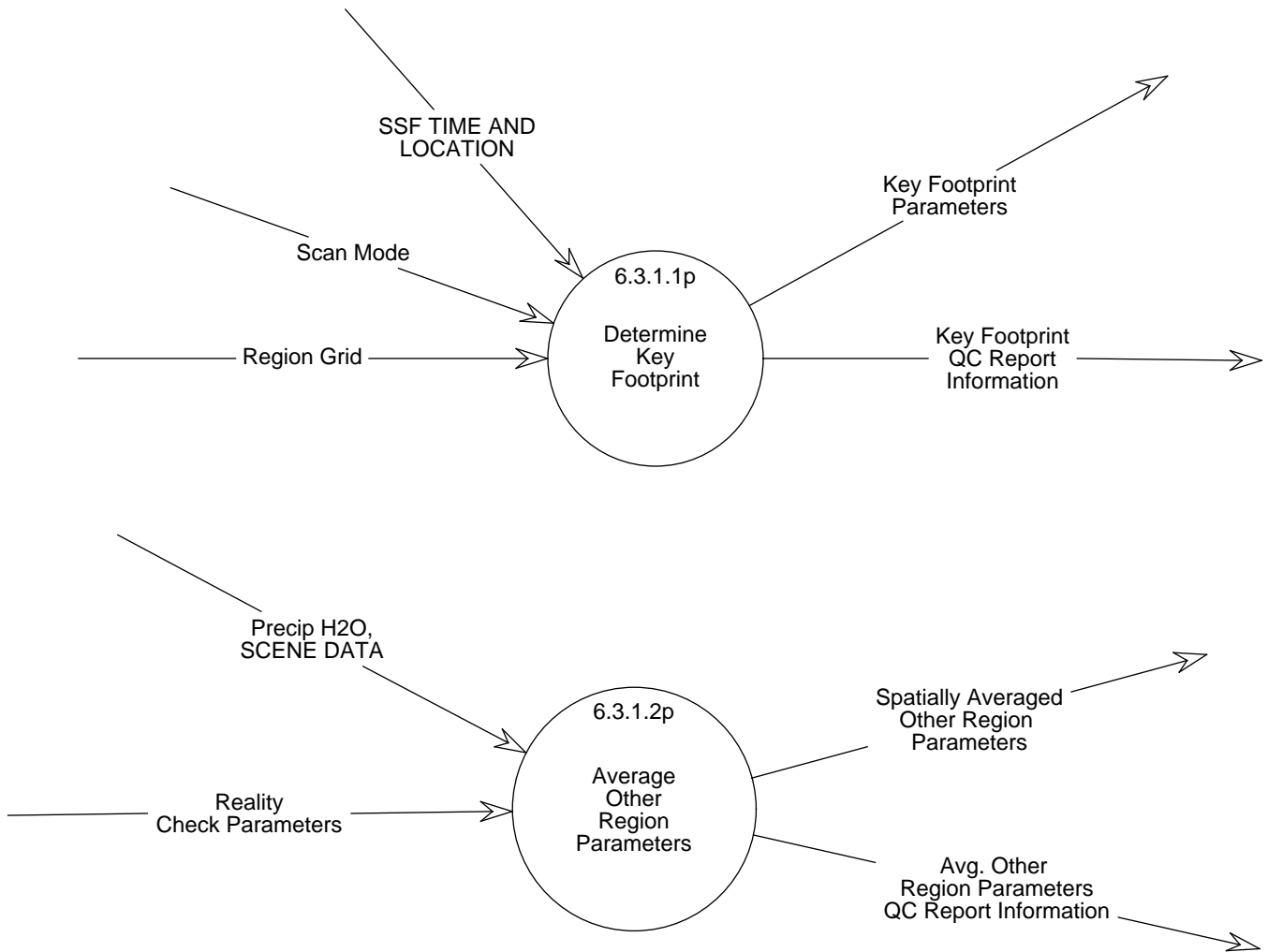
Figure 5-4. Data Flow Diagram for Average Region Parameters

5.2.3.1.2 Average Other Region Parameters - Process 6.3.1.2

Input Data Flows
        Precip H2O
        Reality Check Parameters
        SCENE DATA

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 spatial average 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 verify that they are within specified limits.

[22] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

5.2.3.2 Average Radiative Flux Parameters - Process 6.3.2

Input Data Flows
        ATMOSPHERIC FLUX PROFILE
        Clear-Sky/Total-Sky Flag
        FLUX ADJUSTMENTS
        OBSERVED TOA DATA
        Reality Check Parameters
        Scan Mode

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 radiative flux parameters. For Release 1, simple arithmetic means and standard deviations will be calculated.

The decomposition for this function is shown in Figure 5-5.

5.2.3.2.1 Calculate Total Sky Fluxes - Process 6.3.2.1

Input Data Flows
        ATMOSPHERIC FLUX PROFILE
        Clear Sky/Total Sky Flag
        FLUX ADJUSTMENTS
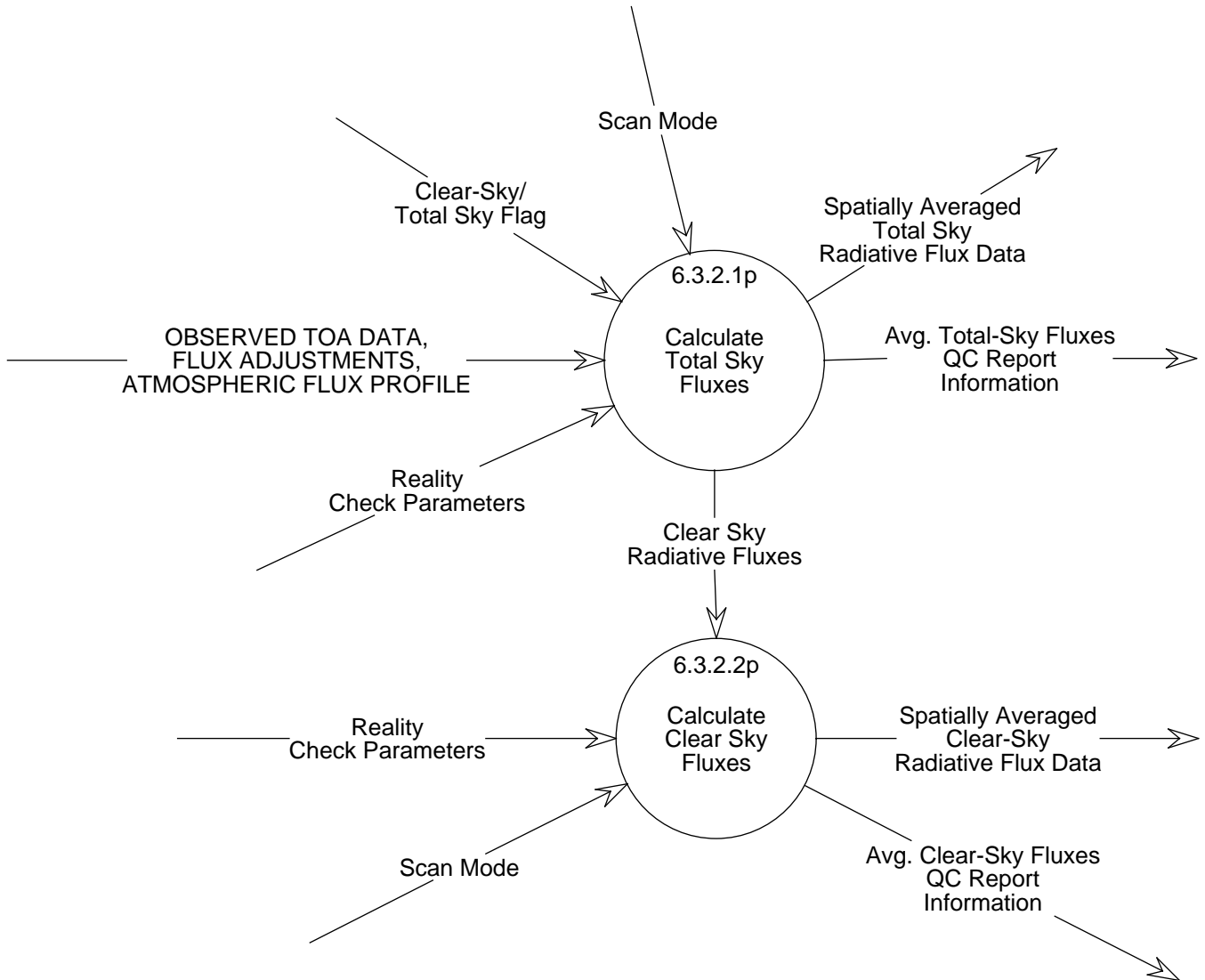   OBSERVED TOA DATA
        Reality Check Parameters

Figure 5-5. Data Flow Diagram for Average Radiative Flux Parameters

Scan Mode

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 CRS data product. The clear-sky footprints shall be used in the calculation of total-sky averages, and shall also be passed to Process 6.3.2.2, 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:

$$\tilde{x} = \left(\sum_i \tilde{x}_i \right) / N \tag{1}$$

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. observed - untuned SARB SW flux at TOA
5. observed - tuned SARB SW flux at TOA
6. observed - untuned SARB LW flux at TOA
7. observed - tuned SARB LW flux at TOA
8. tuned SW downward fluxes at surface
9. tuned SW upward fluxes at surface
10. tuned LW downward fluxes at surface
11. tuned LW upward fluxes at surface
12. tuned - untuned SW downward fluxes at surface
13. tuned - untuned SW upward fluxes at surface
14. tuned - untuned LW downward fluxes at surface
15. tuned - untuned LW upward fluxes at surface
16. tuned SW downward flux at atmospheric levels
17. tuned SW upward flux at atmospheric levels
18. tuned LW downward flux at atmospheric levels
19. tuned LW upward flux at atmospheric levels

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

Atmospheric levels for Release 1 are currently defined as 500 hPa and the tropopause.

[25] If Subsystem 5.0 cannot provide parameters 4 - 7, the observed minus tuned and observed minus untuned fluxes, this process shall calculate those differences in fluxes prior to calculating averages and variances of the differences.

[26] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of the these checks as QC report information to the Process 6.4, Build QC Report.

[27] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.5, Build QC Report.

5.2.3.2.2 Calculate Clear Sky Fluxes - Process 6.3.2.2

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):

[28] This process shall calculate means and standard deviations of radiative flux parameters for clear-sky footprints.

For Release 1, the mean value $\tilde{x}$ of parameter x in a given regional hour box is defined by equation (1), and the standard deviation s is defined by equation (2).

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. observed - untuned SARB SW flux at TOA
5. observed - tuned SARB SW flux at TOA
6. observed - untuned SARB LW flux at TOA
7. observed - tuned SARB LW flux at TOA
8. tuned SW downward fluxes at surface

9. tuned SW upward fluxes at surface
10. tuned LW downward fluxes at surface
11. tuned LW upward fluxes at surface
12. tuned - untuned SW downward fluxes at surface
13. tuned - untuned SW upward fluxes at surface
14. tuned - untuned LW downward fluxes at surface
15. tuned - untuned LW upward fluxes at surface
16. tuned SW downward flux at atmospheric levels
17. tuned SW upward flux at atmospheric levels
18. tuned LW downward flux at atmospheric levels
19. tuned LW upward flux at atmospheric levels

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

Atmospheric levels for Release 1 are currently defined as 500 hPa and the tropopause.

[29] If Subsystem 5.0 cannot provide parameters 4 - 7, the observed minus tuned and observed minus untuned fluxes, this process shall calculate those differences in fluxes prior to calculating averages and variances of the differences.

[30] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of the these checks as QC report information to Process 6.4, Build QC Report.

[31] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

5.2.3.3 Average Cloud Parameters - Process 6.3.3

Input Data Flows
CLD LAYER ADJUSTMENTS
FOOTPRINT CLOUD PROPERTIES
OVERLAP FOOTPRINT DATA
Reality Check Parameters

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

Process Description (Figure 5-3):

This process calculates the spatial averages and standard deviations of cloud parameters. Three types of cloud data are included in the FSW data product. These are cloud overlap conditions, cloud category properties, and weighted column-averaged cloud properties. For Release 1, simple arithmetic means and standard deviations of the various cloud parameters will be calculated.

The decomposition for this function is shown in Figure 5-6.

5.2.3.3.1 Average Cloud Overlap Conditions - Process 6.3.3.1

Input Data Flows
> OVERLAP FOOTPRINT DATA
> Reality Check Parameters

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

Process Specification (Figure 5-6):

[32] This process shall calculate arithmetic means and standard deviations of the cloud overlap conditions. These are the fractional area coverage for each of the following eleven conditions:

1. Clear (CL)
2. Low Cloud (L)
3. Lower Middle Cloud (LM)
4. Upper Middle Cloud (UM)
5. High Cloud (H)
6. H/UM Cloud
7. H/LM Cloud
8. H/L Cloud
9. UM/LM Cloud
10. UM/L Cloud
11. LM/L Cloud

[33] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of the these checks as QC report information to Process 6.4, Build QC Report.

[34] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

Figure 5-6. Data Flow Diagram for Average Cloud Parameters

5.2.3.3.2 Average Cloud Category Properties - Process 6.3.3.2

Input Data Flows
>CLD LAYER ADJUSTMENTS
>FOOTPRINT CLOUD PROPERTIES
>Reality Check Parameters

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

Process Description (Figure 5-6):

This process calculates the means and standard deviations of the cloud category properties. The three types of cloud category properties are cloud area fractions, cloud properties, and optical depth/IR emissivity histogram.

The decomposition for this function is shown in Figure 5-7.

Figure 5-7. Data Flow Diagram for Average Cloud Category Properties

5.2.3.3.2.1 Average Cloud Area Fraction - Process 6.3.3.2.1

Input Data Flows

       Frac Tot Cld Area
       Reality Check Parameters

Output Data Flows

       Avg. Cloud Area Fraction QC Report Information
       Spatially Averaged Cloud Area Fractions

Process Specification (Figure 5-7):

[35] This process shall calculate arithmetic means and standard deviations of cloud area fraction for overcast, broken, and total clouds for each cloud category for each regional hour box. Cloud categories are High, Upper Middle, Lower Middle, and Low clouds.

[36] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of the these checks as QC report information to Process 6.4, Build QC Report.

[37] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.
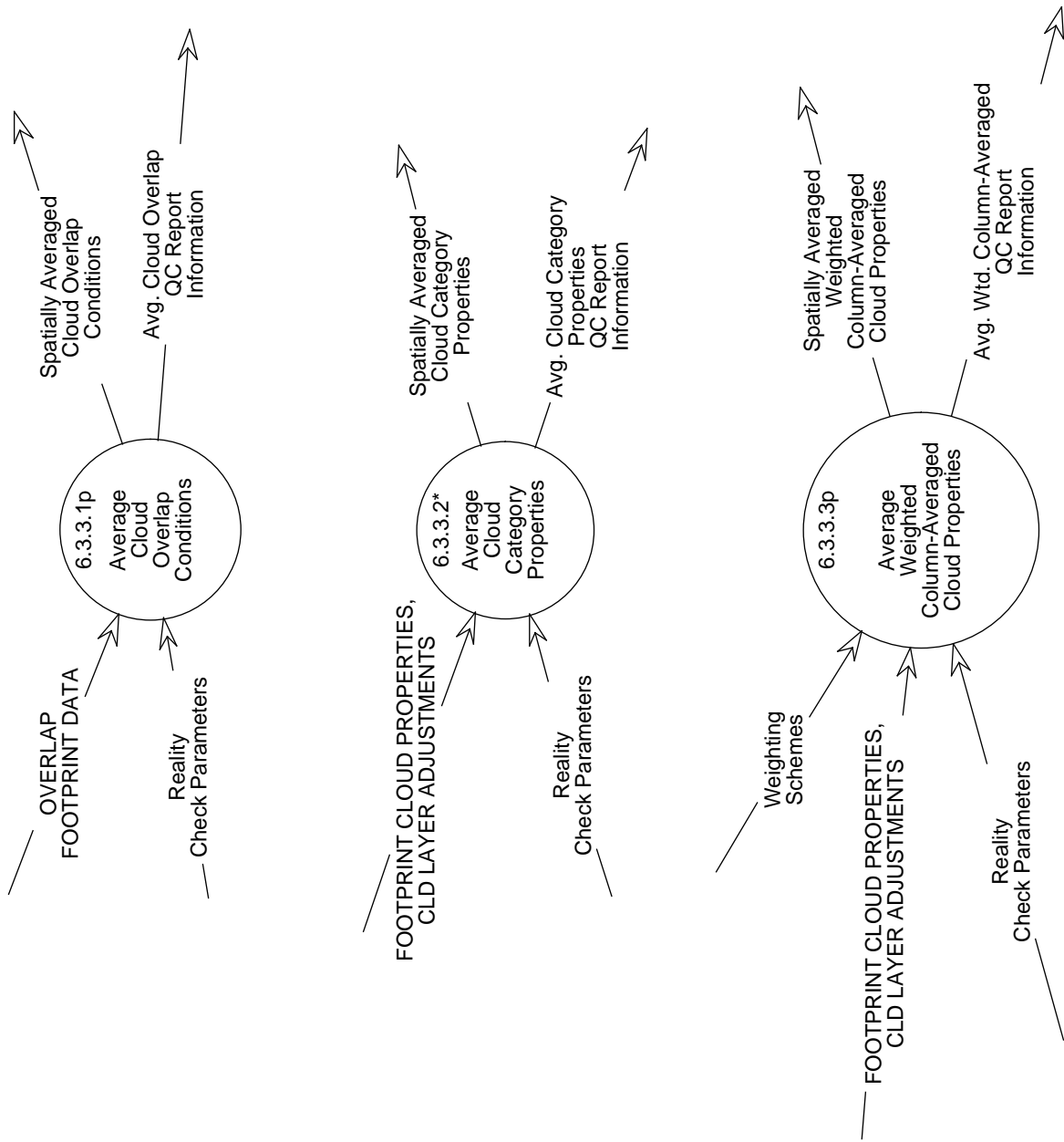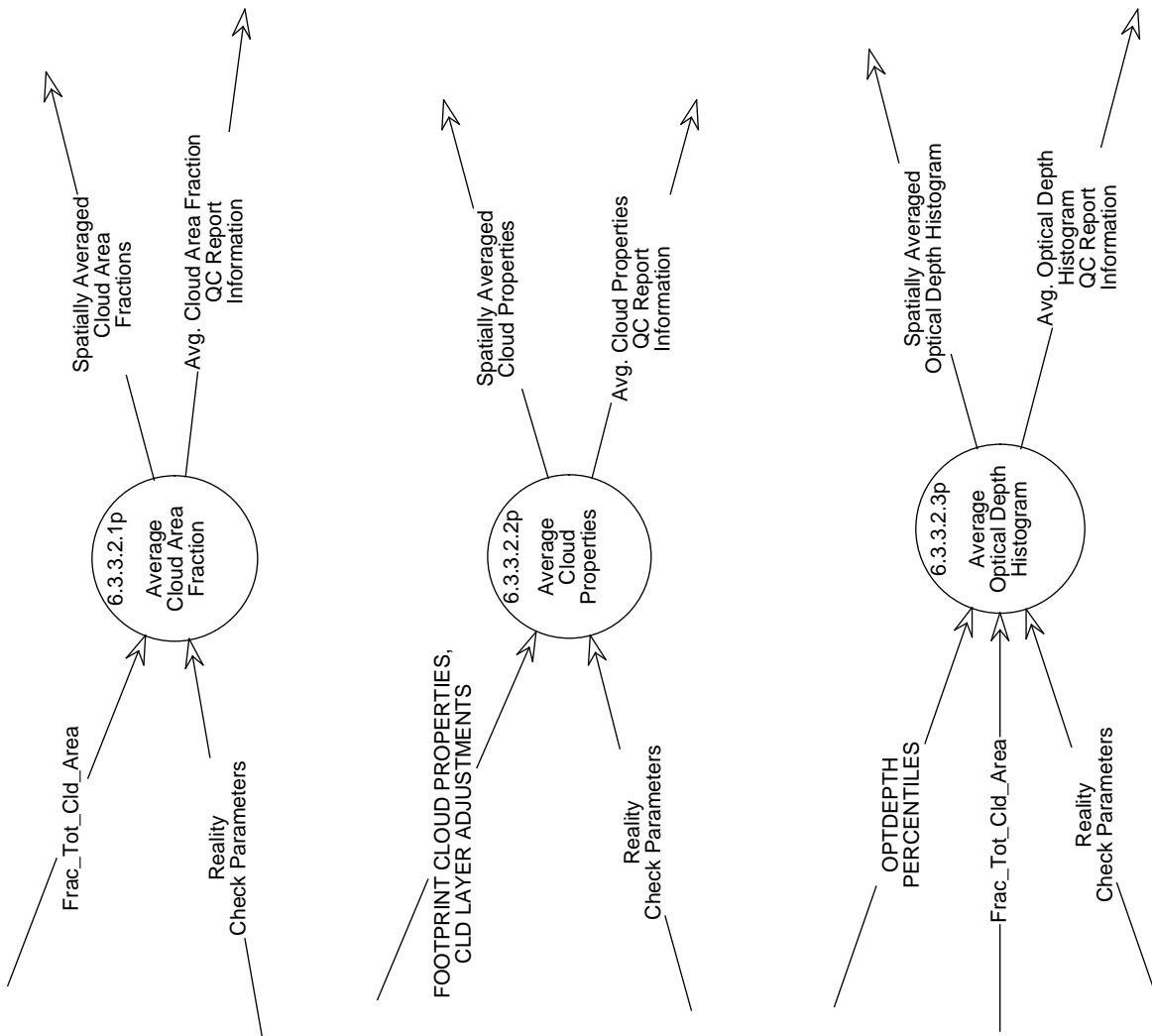
5.2.3.3.2.2 Average Cloud Properties - Process 6.3.3.2.2

Input Data Flows

       CLD LAYER ADJUSTMENTS
       FOOTPRINT CLOUD PROPERTIES
       Reality Check Parameters

Output Data Flows

       Avg. Cloud Properties QC Report Information
       Spatially Averaged Cloud Properties

Process Specification (Figure 5-7):

[38] This process shall calculate arithmetic means and standard deviations of cloud properties for each cloud category for each regional hour box.

Cloud categories are High, Upper Middle, Lower Middle, and Low clouds. The cloud properties to be averaged for each category 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
14. Adjusted IR emissivity
15. Adjusted fractional area
16. Adjusted effective temperature
17. Adjusted visible optical depth

The average cloud property is weighted by the fractional area of cloud in each footprint in a regional hour box. For Release 1, the average cloud property $\tilde{x}$ is defined by:

$$\tilde{x} = \frac{\sum_i f_i x}{\sum_i f_i} \tag{3}$$

where f_i is the fractional cloud area in footprint i, and x is the value of a given cloud property in footprint i.

For Release 1, the standard deviation of cloud properties over a regional hour box will be calculated from the variance of the properties over each footprint. The CERES Science Team will provide the equations for the variance.

[39] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of these checks as QC report information to Process 6.4, Build QC Report.

[40] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

5.2.3.3.2.3 Average Optical Depth Histogram - Process 6.3.3.2.3

Input Data Flows
     Frac Tot Cld Area
     OPTDEPTH PERCENTILES
     Reality Check Parameters

Output Data Flows
       Avg. Optical Depth Histogram QC Report Information
       Spatially Averaged Optical Depth Histogram

Process Specification (Figure 5-7):

[41] This process shall determine a regional mean histogram of visible optical depth (day) and infrared emissivity (night) for each of four cloud height categories (low, lower middle, upper middle, and high) for each regional hour box.

For Release 1, the following algorithm will be used:

In each regional hour box n, for each cloud height category m, for each CERES footprint, retrieve the optical depths or IR emissivities $\{x_{ki}\}$ corresponding to the percentile values $\{p_k\}$ for $k \in [1, 13]$. Reconstruct the histogram on a fine optical depth grid consisting of a set of points $\{z_j\}$ for $j \in [1, 50]$.

Average the reconstructed histograms $\{p_{ji}\}$ over all footprints in the regional hour box weighted by the fractional cloud area f_i, to obtain a regional mean histogram $\{P_j\}$:

$$\{P_j\} = P(z_j) = \frac{\sum_i f_i p_i(z_j)}{\sum_i f_i} \qquad (4)$$

Linearly interpolate to obtain optical depth or IR emissivity values x_k corresponding to selected percentile values $\{p_k\}$. This is the mean regional optical depth or IR emissivity histogram for cloud height category m for regional hour box n.

[42] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of the these checks as QC report information to Process 6.4, Build QC Report.

[43] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

5.2.3.3.3 Average Weighted Column-Averaged Cloud Properties - Process 6.3.3.3

Input Data Flows
       CLD LAYER ADJUSTMENTS
       FOOTPRINT CLOUD PROPERTIES
       Reality Check Parameters
       Weighting Schemes

Output Data Flows
> Avg. Wtd Column-Averaged QC Report Information
> Spatially Averaged Weighted Column-Averaged Cloud Properties

Process Specification (Figure 5-6):

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

[44] 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
14. Adjusted IR emissivity
15. Adjusted fractional area
16. Adjusted effective temperature
17. Adjusted visible optical depth

[45] This process shall first calculate weighted column-averaged cloud properties for each footprint in a region and shall then calculate spatially averaged weighted column-averaged cloud properties for each region.

[46] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of these checks as QC report information to Process 6.4, Build QC Report.

[47] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

5.2.3.4 Average Angular Model Scene Type Parameters - Process 6.3.4

Input Data Flows
> Angular Model Scene Type
> Reality Check Parameters

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

[48] 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

[49] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of the these checks as QC report information to Process 6.4, Build QC Report.

[50] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

5.2.3.5 Average Surface Only Parameters - Process 6.3.5

Input Data Flows
> Reality Check Parameters
> SURFACE ONLY

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

Process Specification (Figure 5-3):

[51] This process shall calculate, for each regional hour box, mean and standard deviations of the photosynthetically action radiation and of the direct/diffuse ratio:

For Release 1, the regional mean direct/diffuse ratio will be computed on a flux-weighted basis, so that the regional mean ratio applies to the regional mean values of direct, diffuse, and total downward shortwave flux.

[52] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of the these checks as QC report information to Process 6.4, Build QC Report.

[53] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

5.2.3.6 Average Adjustment Parameters - Process 6.3.6

Input Data Flows
> CLEAR SKY ADJUSTMENTS
> Reality Check Parameters

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

Process Specification (Figure 5-3):

[54] This process shall calculate, for each regional hour box, the means and standard deviations of the following adjustment parameters:

1. Adjusted precipitable water
2. Adjusted surface albedo
3. Adjusted aerosol optical depth
4. Adjusted skin temperature

[55] This process shall perform a reality check on each of the averaged parameters to verify that they are within specified limits and shall pass the results of the these checks as QC report information to Process 6.4, Build QC Report.

[56] This process shall pass the spatially averaged parameters to Process 6.5, Build Output Product, and the QC report information to Process 6.4, Build QC Report.

5.2.4 Build QC Report - Process 6.4

Input Data Flows
> Avg. Parameters QC Report Information
> CRS Header
> Regional Hour Box QC Report Information

Output Data Flows
> FSW Metadata
> FSW QC Information

Process Specification (Figure 5-1):

[57] This process shall build and output the Quality Control (QC) report for each hourly FSW 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

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[58] This process shall output the appropriate FSW metadata parameters as required by EOSDIS.

5.2.5 Build Output Product - Process 6.5

Input Data Flows
      CRS Header
      FSW Spatial Averages in Regional Hour Boxes
      Num Reg

Output Data Flows
      FSW Flux and Clouds Regional Swath

Process Specification (Figure 5-1):

[59] This process shall create and build the FSW archival product from header information and the spatially averaged regional hour box data for each hour.

[60] This process shall create and open a uniquely named output file.

[61] This process shall format and write the header information to the FSW product output file. The header information shall include the CERES data product code for the FSW archival data product, spacecraft identification, CERES instrument identification code, CERES instrument scan mode, data date and time, processing date and time, software version number, and the number of regions (records) in the product.

[62] For each regional hour box, this process shall format and write the spatially averaged data to the FSW product output file.

The averaged regional hour box data includes:

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

5.3 Design Goals and Constraints

The Release 1 design of the Atmospheric 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 object oriented design 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 PGS Toolkit, which are currently under development.

5.4 Resource Use

The estimated size of the FSW hourly product is 4.2 MB. As the definition of the FSW data product matures, this size estimate may change. There will be 24 FSW data products per day per instrument, and 768 per month per instrument. This latter number is based on an average of 30 days per month, plus two days per month for data overlap on the first and last days of the month. Thus, we anticipate a monthly size of 3226 MB. Since the next step in the CERES data processing system operates on a month of data, FSW will require at least 3226 MB of storage space for each data month being processed.

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

References

1. CERES Data Management System Data Products Catalog. Release 1, Version1, August 1994.

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

3. Hazra, R., S.K. Park, G.L. Smith, N.D. Manalo, and S.E. Reichenbach. The Role of Simulation in the Design of Imaging Systems. Presented to Southeastern Simulation Conference, October, 1992, Pensacola, Florida.

4. Hazra, R., S.K. Park, G.L. Smith, and S.E. Reichenbach, 1993. Constrained least-squares image restoration filters for sampled image data, pp 177-192, v. 2028, Proc. Conf. Appl. in Digital Image Proc., A. Tescher (ed), SPIE Internat. Symp. Optical Instru. and Appl. Sci., Proc., San Diego, California.

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
CL	Clear (Cloud overlap condition)
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)
H	High cloud
hPa	hectoPascal
IES	Instrument Earth Scan
INT	Integer
IR	Infrared
ISCCP	International Satellite Cloud Climatology Project
IWP	Ice Water Path
L	Low cloud
LM	Lower Middle cloud
LW	Longwave
LWP	Liquid Water Path
MB	Megabyte
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
P-spec	Process Specification
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)
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
UM   Upper Middle cloud
UT   Universal Time
WN   Window