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

Data Management System

Software Requirements Document

CERES Inversion to Instantaneous TOA Fluxes
and Empirical Estimates of Surface Radiation Budget
Subsystems 4.5 and 4.6

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 one or more stand-alone executable programs. 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

This document provides the Release 1 software requirements for the CERES Inversion to Instantaneous TOA Fluxes and Empirical Estimates of Surface Radiation Budget, Subsystems 4.5 and 4.6, as defined in the CERES Algorithm Theoretical Basis Documents (ATBD) (see References 1 and 2). These requirements will serve as a basis for the software design and test plan for Release 1 of Subsystems 4.5 and 4.6. The software requirements for Subsystems 4.1 through 4.4 will be addressed in a separate document (see Reference 3). The intended audience of this document consists of CERES subsystem design teams, subsystem test teams, and science reviewers.

This document is organized as follows:

Section 1   Introduction - states the purpose of this document, gives a description of its general content, and presents an overview of Subsystem 4.0.

Section 2   Key Concepts - defines the key concepts used throughout this document.

Section 3   Requirements Approach and Tradeoffs - describes the approach taken in the formulation of the Release 1 software requirements for the CERES Inversion to Instantaneous TOA Fluxes and Empirical Estimates of the Surface Radiation Budget, Subsystems 4.5 and 4.6.

Section 4   External Interface Requirements - describes the primary input and output products of Subsystems 4.5 and 4.6.

Section 5   Requirements Specification - provides the operational and functional requirements for Subsystems 4.5 and 4.6, describes the design goals and constraints for the Subsystems, and provides information on resource use.

References

Abbreviations, Acronyms, and Symbols

1.2 System Overview

The Cloud Retrieval and Radiative Flux Inversion Subsystem 4.0 is divided into six subsystems that correspond to the CERES ATBD Subsystems 4.1 through 4.6 (see Reference 4). The Cloud Working Group is responsible for Subsystems 4.1 through 4.4, and the Inversion Working Group is responsible for Subsystems 4.5 and 4.6. The Surface and Atmospheric Radiation Budget (SARB) working group will provide the algorithms for Subsystem 4.6. The six subsystems described in the CERES ATBD under Subsystem 4 are the following:

1. Subsystem 4.1, *Imager Clear-Sky Determination and Cloud Detection*, will collect ancillary input information for each imager pixel; determine the surface conditions and classify each pixel as clear, cloudy, or uncertain; and determine a cloud mask (see References 3 and 4).

2. Subsystem 4.2, *Cloud Pressure Retrieval*, will determine cloud macrophysical properties for cloudy pixels (see References 3 and 4).

3. Subsystem 4.3, *Cloud Optical Property Retrieval*, will determine cloud microphysical properties for cloudy pixels (see References 3 and 4).

4. Subsystem 4.4, *Convolution of Imager Cloud Properties with CERES Footprint Point Spread Function (PSF)*, will map imager pixel cloud properties onto the CERES footprint and calculate cloud statistics over the footprint (see References 3 and 5).

5. Subsystem 4.5, *CERES Inversion to Instantaneous TOA Fluxes*, will determine the CERES Inversion shortwave (SW) and longwave (LW) scene types based on the surface type and cloud parameters for each CERES footprint and will derive CERES unfiltered SW, LW, and window (WN) radiances by applying spectral correction coefficients to filtered SW, total (TOT), and WN radiances. The unfiltered radiances will be inverted to instantaneous top-of-atmosphere (TOA) fluxes (see Reference 1).

6. Subsystem 4.6, *Estimate Surface Radiation Budget*, will empirically estimate the SW net and LW downward and LW net surface fluxes based on TOA fluxes, cloud properties, and

meteorological data (see Reference 2). A place holder for the SW downward surface flux parameter is also stored for each CERES footprint. An algorithm for empirically estimating SW downward surface flux has not been identified for Release 1 but may be available for future releases of the software

Subsystem 4 software will be designed as two software packages. The software for Subsystems 4.1 through 4.4 will generate a preliminary Single Satellite CERES Footprint TOA and Surface Fluxes, Clouds (SSF) file. This SSF file will be input data to the Subsystems 4.5 and 4.6 software, which will fill in scene types, unfiltered radiances, and TOA and surface flux parameters on each footprint and create an SSF archival product using Science Data Production (SDP) toolkit calls (see Reference 6). The software requirements for Subsystems 4.1 through 4.4 will be described in a separate document (see Reference 3).

2.0 Key Concepts

The following key concepts are associated with Subsystems 4.5 and 4.6:

Angular distribution models (ADM) are a set of values used to correct for the anisotropy of the radiation field when deriving radiative flux using scanner radiance observations.   LW radiance ADMs (limb-darkening models) are a function of scene type, viewing zenith, and colatitude, while SW radiance ADMs (bidirectional models) are a function of Inversion scene type and three angles: satellite viewing zenith, solar zenith, and relative azimuth between the Sun and the satellite. A detailed description of the ERBE ADMs, which will be used for Release 1 and Release 2 of the CERES software, is contained in Section 4.1 of this document.

During the 18 months following the TRMM launch, the Inversion WorkingGroup will be preparing a new set of SW, LW, and WN channel ADMS. These new CERES ADMs will be used as part of the Release 3 data processing system to invert SW, LW, and WN channel unfiltered radiance measurements to fluxes at the TOA. It is anticipated that previously calculated TOA fluxes based on ERBE ADMs will be recalculated using the new CERES ADMs. The surface fluxes will also be recalculated and stored on the SSF product.

CERES footprint is defined as a single CERES field-of-view (FOV). Cloud imager derived properties will be convolved with the CERES PSF and will be matched to the CERES footprint (see Reference 5).

CERES Inversion scene types will be based on a combination of geographic surface types and cloud properties. SW and LW scene types will be defined by examining the TRMM data and the accompanying cloud properties. For Release 1 and Release 2, the twelve ERBE scene types will be used as the CERES inversion scene types (see Reference 1).

ERBE Inversion scene types are scene identification types based on a combination of the five geographic surface types (ocean, land, snow, desert, and coastal or ocean-land mix) and four basic cloud covers which are listed in Table 5-1. The twelve ERBE scene types are listed in Table 5-2.

CERES Spectral Correction Scene Types are the same for CERES as for ERBE. There are five scenes [ocean, land, desert, snow, cloud] and three colatitudinal zones [tropical, mid-latitude, polar] for a total of 12 Spectral Correction Scene Types as listed in Table 5-3.

Spectral correction coefficients are sets of constants which correct the radiometric measurements for the imperfect spectral response of the instruments. There are separate sets of coefficients for daytime and nighttime measurements. Section 4.3 of this document contains a detailed description of the CERES spectral correction coefficients file, SCCOEF (see References 7).

3.0 Requirements Approach and Tradeoffs

The CERES Inversion to Instantaneous TOA Fluxes and the Empirical Estimates of Surface Radiation Budget, Subsystems 4.5 and 4.6, software requirements were formulated based on the CERES Algorithm Theoretical Basis Document for Subsystems 4.5 and 4.6 (see References 1 and 2) and meetings with the CERES Science Team and Data Management Team.

The requirements approach for Subsystems 4.5 and 4.6 takes into account the plan for CERES software to be designed in three releases.   The first two releases of the software will be completed prior to the launch of the TRMM satellite and the third release is expected to be operational 18 months after the TRMM launch. Release 1 software will process global data from the existing ERBE/AVHRR/High Resolution Infrared Radiation Sounder (HIRS) data from the NOAA-9 and NOAA-10 spacecraft and will be used to test algorithm concepts.   Release 2 software will process data from the CERES Instruments.   Based on the processing analysis of Release 2 data, the Inversion Working Group will develop a set of SW, LW and WN channel CERES ADMs. Release 3 software will use these improved ADMs to derive TOA flux estimates for each CERES footprint. Until the new CERES ADMs are available, the ERBE ADMs will be used (see Reference 1).

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.
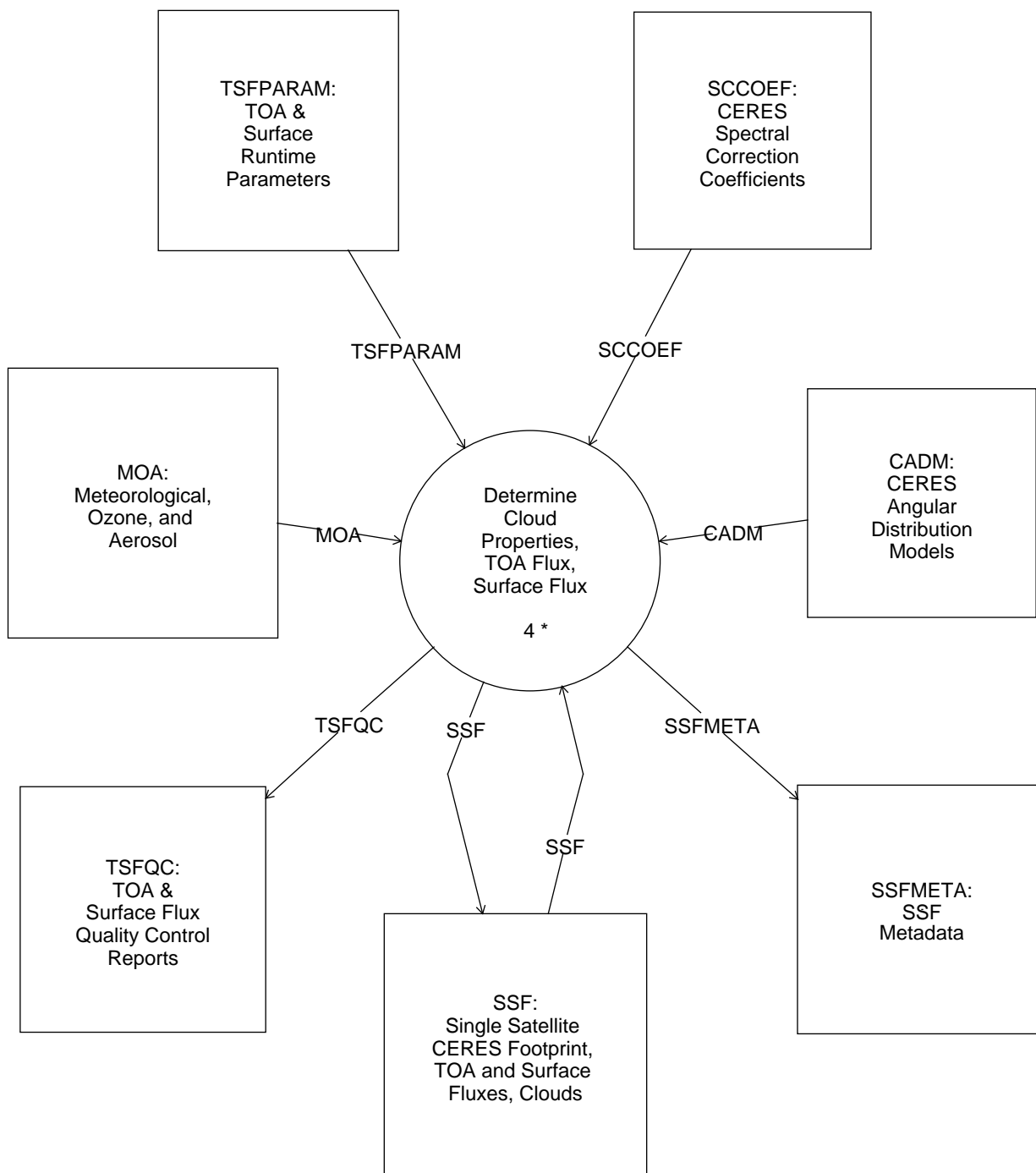
Figure 4-1. Context Diagram

4.1 CADM

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

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

The CERES Inversion Working Group will generate and maintain the CADMs. The CADMs will be updated for Release 3, after analyzing the results from approximately 18 months of CERES processing using data from the CERES Rotating Azimuth Plane Scanner (RAPS) (see Reference 1).

4.2 MOA

The MOA, a CERES archival product, is produced by the CERES Regrid Humidity and Temperature Subsystem. Each MOA file contains meteorological, ozone, and aerosol data for 1-hour, and is used by several of the CERES subsystems. Data on the MOA are derived from several data sources external to the CERES system, such as the National Meteorological Center (NMC), the Moderate Resolution Imaging Spectrometer (MODIS), the Stratospheric Aerosols and Gases Experiment (SAGE), and various other sources. These data arrive at intervals ranging from four times daily to once a month, and are horizontally and vertically organized differently from what the CERES system requires. The Regrid Humidity and Temperature Subsystem interpolates these data temporally, horizontally, and vertically to conform with CERES processing requirements. A detailed list of the parameters included on the MOA product is given in Reference 8.

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

The MOA contains:
 • Surface temperature and pressure.

- Vertical profiles of temperature, humidity, and geopotential height as a function of pressure for the internal atmospheric levels requested by the Clouds and SARB Working Groups.

- Column precipitable water.

- Vertical ozone profiles for internal atmospheric levels requested by the SARB Working Group.

- Column ozone.

- Total column aerosol.

- Stratospheric aerosol.

The internal atmospheric levels, in hPa, as requested by the CERES Clouds and SARB Working Groups as of December 1993 are listed in Table 4-1. It should be noted that prior to Release 2, the number of levels most likely will change from 38. Also, the levels themselves may change.

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

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

4.3 SCCOEF

The spectral correction coefficient file, SCCOEF, contains data which correct the radiometric measurements for the imperfect spectral response of the optical path in the CERES instrument. The spectral correction data consists of parameters and spectral correction coefficients which are used in calculating the SW, LW, and WN unfiltered radiance estimates from the SW, TOT, and WN scanner measurements. The spectral correction coefficient algorithm requires both daytime and nighttime coefficients. Up to nine of these coefficients must be selected for each CERES footprint based on spacecraft geometry, Spectral Correction Scene Type, and the availability of data from the three scanner channels. The daytime coefficients are a function of 12 CERES Spectral Correction Scene Types, four satellite viewing zenith bins, four solar zenith bins, five relative azimuth bins, and an index reflecting channel data availability. The nighttime coefficients are a function of 12 CERES Spectral Correction Scene Types, four viewing zenith bins, and an

index reflecting channel data availability. The spectral correction coefficient data files are spacecraft platform dependent.

4.4 SSF

The Single Satellite CERES Footprint TOA and Surface Fluxes, Clouds (SSF) is produced from the cloud identification, inversion, and surface processing for CERES. Each SSF covers a single hour swath from a single CERES scanner (3 channels) mounted on one satellite. The product has a product header and multiple records of approximately 125 parameters or 315 elements for each footprint.

The major categories of data output on the SSF are
> 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)

The SSF is an archival product that will be run daily in validation mode starting with the TRMM launch until sufficient data have been collected and analyzed to produce a production quality set of CERES Angular Distribution Models (CADM). It is estimated that at TRMM launch plus 18 months, the SSF product will be produced on a routine basis and will be archived within EOSDIS for distribution. A detailed list of the parameters included on the SSF product is given in Reference 8.

4.5 SSFMETA

The SSF metadata file, SSFMETA, will contain metadata for the SSF archival product. The contents and format of SSFMETA will be consistent with the EOSDIS Core System (ECS) Requirements (see Reference 9).

4.6 TSFPARAM

The TOA and Surface Flux Parameter file, TSFPARAM, contains processing information required to initiate and execute the CERES Inversion to Instantaneous TOA Fluxes and Empirical Estimates of Surface Radiation Budget, Subsystems 4.5 and 4.6, software.

4.7 TSFQC

TSFQC contains the quality control reports produced by the CERES Inversion to Instantaneous TOA Fluxes and Estimates of Surface Radiation Budget, Subsystems 4.5 and 4.6. Information provided in these reports will include:

- Spacecraft and instrument identification
- Data date and temporal span
- Processing date and time of the CERES Inversion to Instantaneous TOA Fluxes and Empirical Estimates of Surface Radiation Budget, Subsystems 4.5 and 4.6
- Software version number of the CERES Inversion to Instantaneous TOA Fluxes and Empirical Estimates of Surface Radiation Budget, Subsystems 4.5 and 4.6
- Processing date and time of Determine Cloud Properties Subsystem
- Software version number of Determine Cloud Properties Subsystem
- CADM version number
- SCCOEF version number
- Number of CERES footprints processed
- Diagnostic messages
- Scene ID data
- Statistical data for the following:
  - Spectral Correction Algorithm
  - Scene ID
  - TOA flux
  - Surface Flux

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, the final subparagraph in this section identifies design goals which will be addressed during the design of the system. These goals are distinguished from the requirements by the fact that it is not possible to include formal tests for the design goals in the system test plan.

5.1 Operating Modes

There are two operating modes for the CERES Inversion to Instantaneous TOA Fluxes and the Empirical Estimates of Surface Radiation Budget, Subsystems 4.5 and 4.6. The first is an initial processing mode which will use SSF input created by the Determine Cloud Properties Subsystem (see Reference 3). The second is a reprocessing mode which will input data from an SSF archival product. The SSF input data for the initial processing mode and the reprocessing mode will be in the same format. Both operating modes will use the same algorithms to process the data, but the reprocessing mode will not require the estimates of the unfiltered radiance on the footprints to be recalculated.

5.2 Functional Requirements

This section identifies the specific functional requirements for Release 1 of the CERES Inversion to Instantaneous TOA Fluxes and the Empirical Estimates of Surface Radiation Budget, Subsystems 4.5 and 4.6. These requirements are a subset of the requirements for the Cloud Retrieval and Radiative Flux Inversion Subsystem 4 and are depicted graphically in the Data Flow Diagram for Level 0 (Figure 5-1).   The requirements for the Determine Cloud Properties Subsystem, Subsystems 4.1 through 4.4, can be found in a separate software requirements document (SRD) (see Reference 3). The subparagraphs following the Data Flow Diagram for Level 0 provide the detailed process specifications for processes 4.5 and 4.6 (Figure 5-1). Processes that are decomposed into subprocesses include an "*" in the diagram beside the process number. If there is no further decomposition of the process, the diagram will include a "p" beside the process number. The process specifications will be used to define the testing requirements for Release 1 of the CERES system in the system test plan.
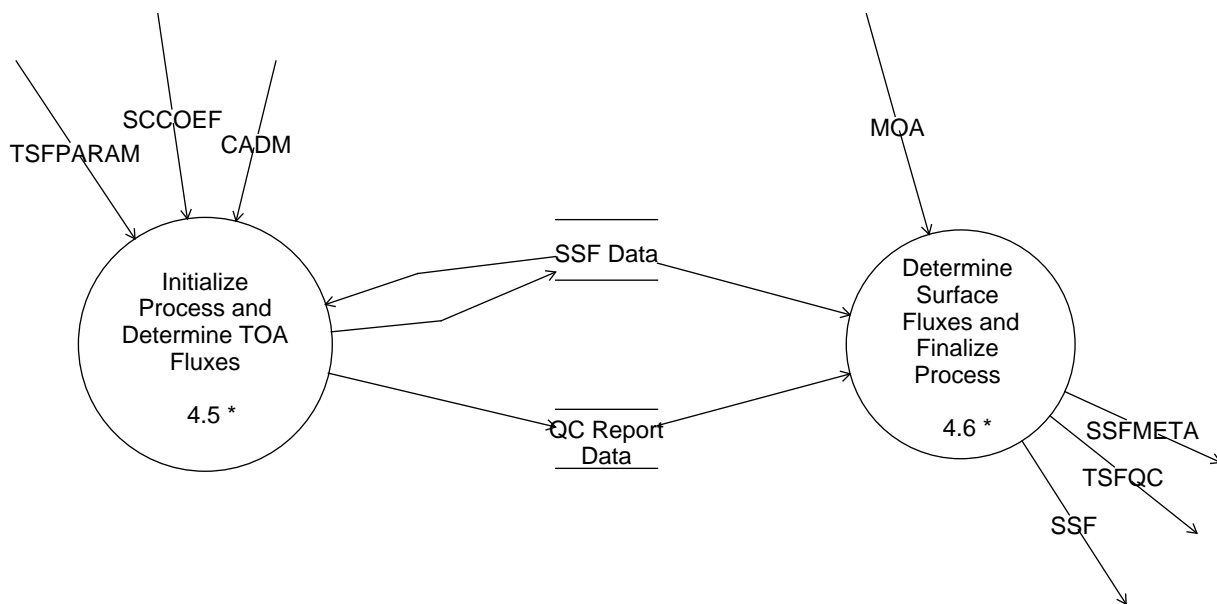
Figure 5-1. Data Flow Diagram for Level 0

5.2.1 Initialize Process and Determine TOA Fluxes - Process 4.5

Input Data Flows
>   CADM
>   SCCOEF
>   SSF Data
>   TSFPARAM

Output Data Flows
>   QC Report Data
>   SSF Data

Process Description (Figure 5-1):

This process will input data and process CERES SW, TOT, and WN measured radiances to instantaneous SW, LW, and WN TOA fluxes for each CERES footprint. This process is decomposed into subprocesses which accomplish the following tasks:

- • Read and process input, Process 4.5.1
- • Determine the inversion SW and LW scene types, Process 4.5.2
- • Calculate Anisotropy for SW and LW from ADMs, Process 4.5.3

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- Apply spectral correction algorithm to filtered radiance measurements, Process 4.5.4
- Invert the unfiltered radiance data to SW, LW, and WN TOA flux estimates, Process 4.5.5

The decomposition of this function is shown in Figure 5-2.

Figure 5-2. Data Flow Diagram for Initialize_Process_and_Determine_TOA_Fluxes

5.2.1.1 Process Input Record - Process 4.5.1

Input Data Flows
> SSF Record
> TSFPARAM

Output Data Flows
> SSF Record
> Viewing Angles

Process Specification (Figure 5-2):

This process is required to perform the following steps:

- Read the inversion and surface flux run-time processing and control parameters from file, TSFPARAM, and input SSF data.
- Initialize the global parameters and constants for inversion and surface flux processing.
- Prepare the header information for the TOA and Surface Flux Quality Control (QC) Report.
- Read each SSF footprint record.
- Determine if it is daytime or nighttime.
- Determine if the SW, TOT, and WN channel radiometric data are available.
- Set channel availability flags.
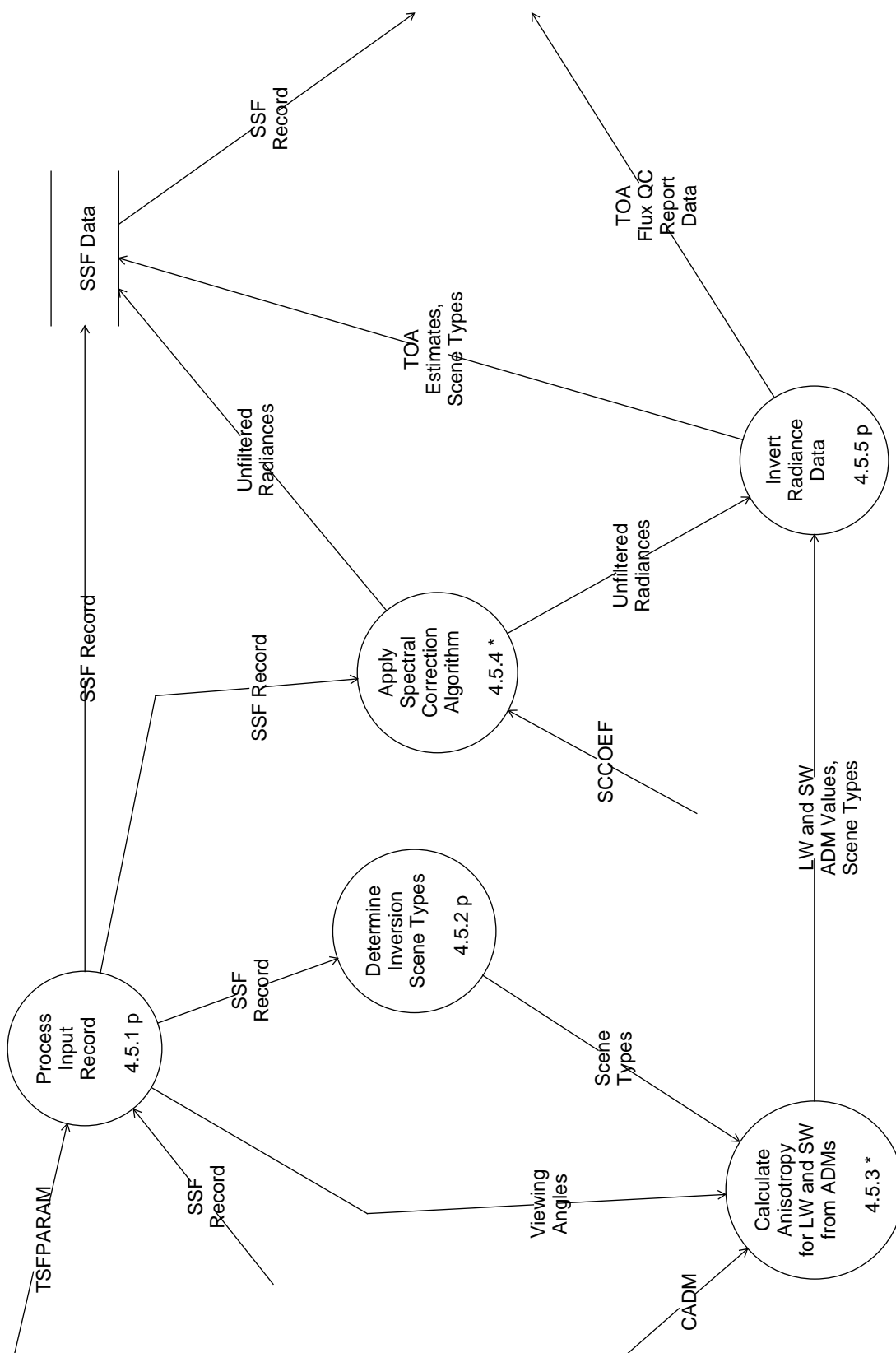
5.2.1.2 Determine Inversion Scene Types - Process 4.5.2

Input Data Flows
> SSF Record

Output Data Flows
> Scene Types

Process Specification (Figure 5-2):

This process will determine the inversion scene types for each CERES footprint based on the footprint surface type and cloud parameters.   For Release 1, the process will select one of the twelve ERBE scene types (seeTable 5-2) which will be used for both the SW and LW scene types. The twelve ERBE inversion scene types are defined as combinations of the five surface types: ocean, land, snow, desert, and coastal, and four cloud conditions (see Table 5-1). The cloud cover is defined as 1 minus the clear area fraction of the CERES footprint. The surface type of the CERES footprint will be defined using the footprint area fractions from the SSF for the three sea types and 10 land types (which sum to 1.0 and are also contained on the CERES footprint) and the following algorithm:

Sum the three sea type fractions to define the ocean fraction
If the ocean fraction is greater than 0.67

Then the footprint surface type will be defined ocean
Else   Sum one or more of the land fractions to define the fraction for snow
       If the snow fraction is greater than 0.50
       Then Set the surface type to snow
       Else Sum one or more of the land fractions to define the fraction for desert
             If the desert fraction is greater than 0.50
             Then Set the surface type to desert
             Else Define the land fraction as 1 - ocean fraction
                   If the land fraction is greater than 0.67
                   Then Set the surface type to land
                   Else Set the surface type to coastal
                   End if
             End if
       End if
End if

Table 5-1. Basic Cloud Categories

Cloud Category	Definition
Clear	0% ≤ cloud cover ≤5%
Partly cloudy	5% < cloud cover ≤50%
Mostly cloudy	50% < cloud cover ≤95%
Overcast	95% < cloud cover ≤100%

Table 5-2. ERBE Inversion Scene Types

Index	Scene Types
1	Clear ocean
2	Clear land
3	Clear snow
4	Clear desert
5	Clear land-ocean mix (coastal)
6	Partly cloudy over ocean
7	Partly cloudy over land or desert
8	Partly cloudy over land-ocean mix
9	Mostly cloudy over ocean
10	Mostly cloudy over land or desert
11	Mostly cloudy over land-ocean mix
12	Overcast

5.2.1.3 Calculate Anisotropy for LW and SW from ADMs - Process 4.5.3

Input Data Flows
> CADM
> Scene Types
> Viewing Angles

Output Data Flows
> Scene Types
> LW and SW ADM Values

Process Description (Figure 5-2):

This process will use a linear interpolation scheme to calculate anisotropy for SW and LW from ADMs. This process decomposes into the following subprocesses:

- Interpolate Anisotropy from SW ADMs, Process 4.5.3.1
- Interpolate Anisotropy from LW ADMs, Process 4.5.3.2

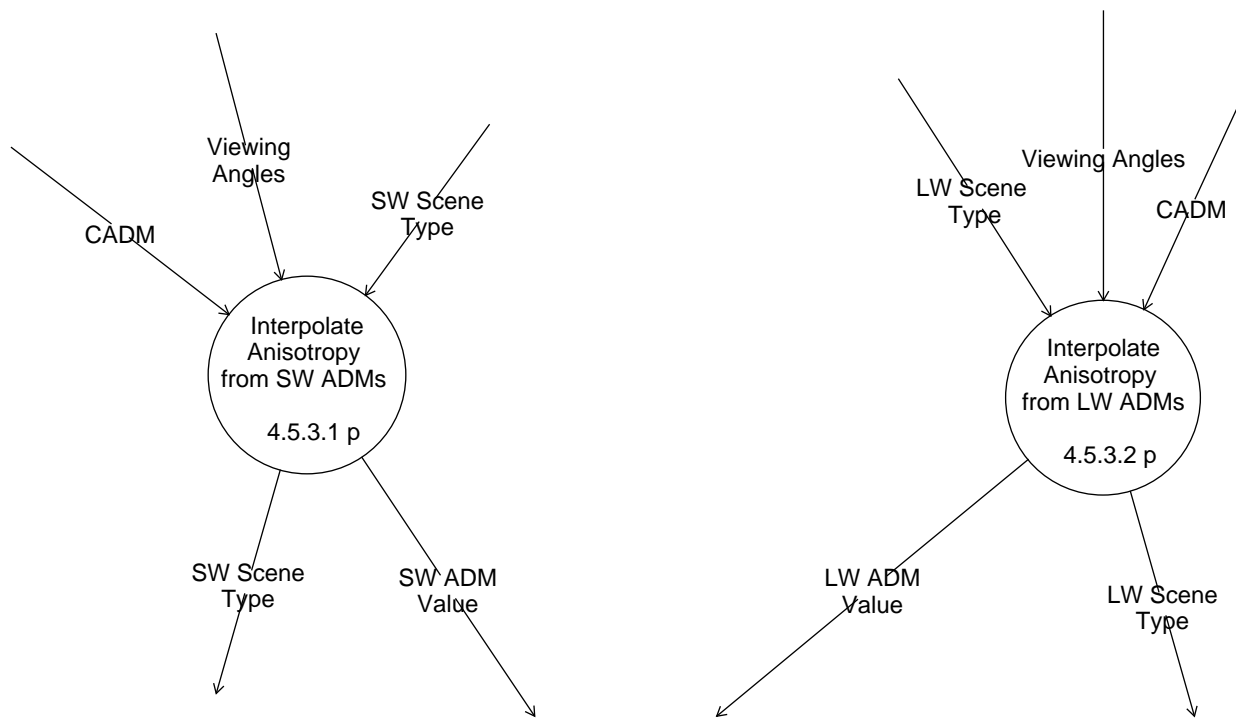The decomposition of this function is shown in Figure 5-3.

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Figure 5-3. Data Flow Diagram for Calculate_Anisotropy_for_LW_and_SW_from ADMs

5.2.1.3.1 Interpolate Anisotropy from SW ADMs - Process 4.5.3.1

Input Data Flows
 CADM
 Viewing Angles
 SW Scene Type

Output Data Flows
 SW Scene Type
 SW ADM Value

Process Specification (Figure 5-3):

This process will perform a trilinear interpolation calculation between grid points in the SW bidirectional model. The interpolation is over the spacecraft zenith, relative azimuth, and solar zenith bins in the SW bidirectional model. Since the area under the interpolated curve is different than the discrete value representation, the resulting smooth function is not normalized to one. The SW model value resulting from the trilinear interpolation must be normalized by dividing by the corresponding SW normalization constant, which is calculated off-line and stored in the CADM file.

5.2.1.3.2 Interpolate Anisotropy from LW ADMs - Process 4.5.3.2

Input Data Flows
> CADM
> Viewing Angles
> LW Scene Type

Output Data Flows
> LW Scene Type
> LW ADM Value

Process Specification (Figure 5-3):

This process will perform a bilinear interpolation calculation between grid points in the LW anisotropic model. The interpolation is over the spacecraft zenith and colatitude bins in the LW anisotropic model. Since the area under the interpolated curve is different than the discrete value representation, the resulting smooth function is not normalized to one. The LW model value resulting from the bilinear interpolation must be normalized by dividing by its corresponding LW normalization constant, which is calculated off-line and stored in the CADM file. For Release 1, the normalized mean ERBE LW model value will also be used to invert the unfiltered WN radiance to TOA flux.

5.2.1.4 Apply Spectral Correction Algorithm - Process 4.5.4

Input Data Flows
> SCCOEF
> SSF Record

Output Data Flows
> Unfiltered Radiances

Process Description (Figure 5-2):

This process applies the spectral correction algorithm which corrects the radiometric measurements for their imperfect spectral response. Radiation from the scene is collected and focused by optics. It passes through a filter, impinges on the detector and causes a signal which is processed and sampled by the electronics, resulting in a filtered measurement. These measurements are collected from the SW, TOT, and WN channels. To correct the filtered signal, the spectral response of the individual channels and the spectral nature of the observed scene are used. The resulting unfiltered radiometric data are stored as SW data ($0 \, \mu m \leq \lambda \leq 5 \, \mu m$), LW data ($\lambda > 5 \, \mu m$) and WN channel data ($8 \, \mu m \leq \lambda \leq 12 \, \mu m$), where λ is the wavelength of the spectral radiance as seen by the instrument (see Reference 7). The spectral correction algorithm selects coefficients from the spectral correction coefficient file and uses these coefficients to unfilter the SW, TOT, and WN channel radiances. This process is decomposed into subprocesses which accomplish the following tasks:

- Determine indexing parameter for mapping the availability of channel data, Process 4.5.4.1
- Determine Spectral Correction Scene Type and angular bin indices, Process 4.5.4.2
- Extract spectral correction coefficients for available channels, Process 4.5.4.3
- Calculate composite spectral correction coefficients, Process 4.5.4.4
- Calculate unfiltered radiance data, Process 4.5.4.5

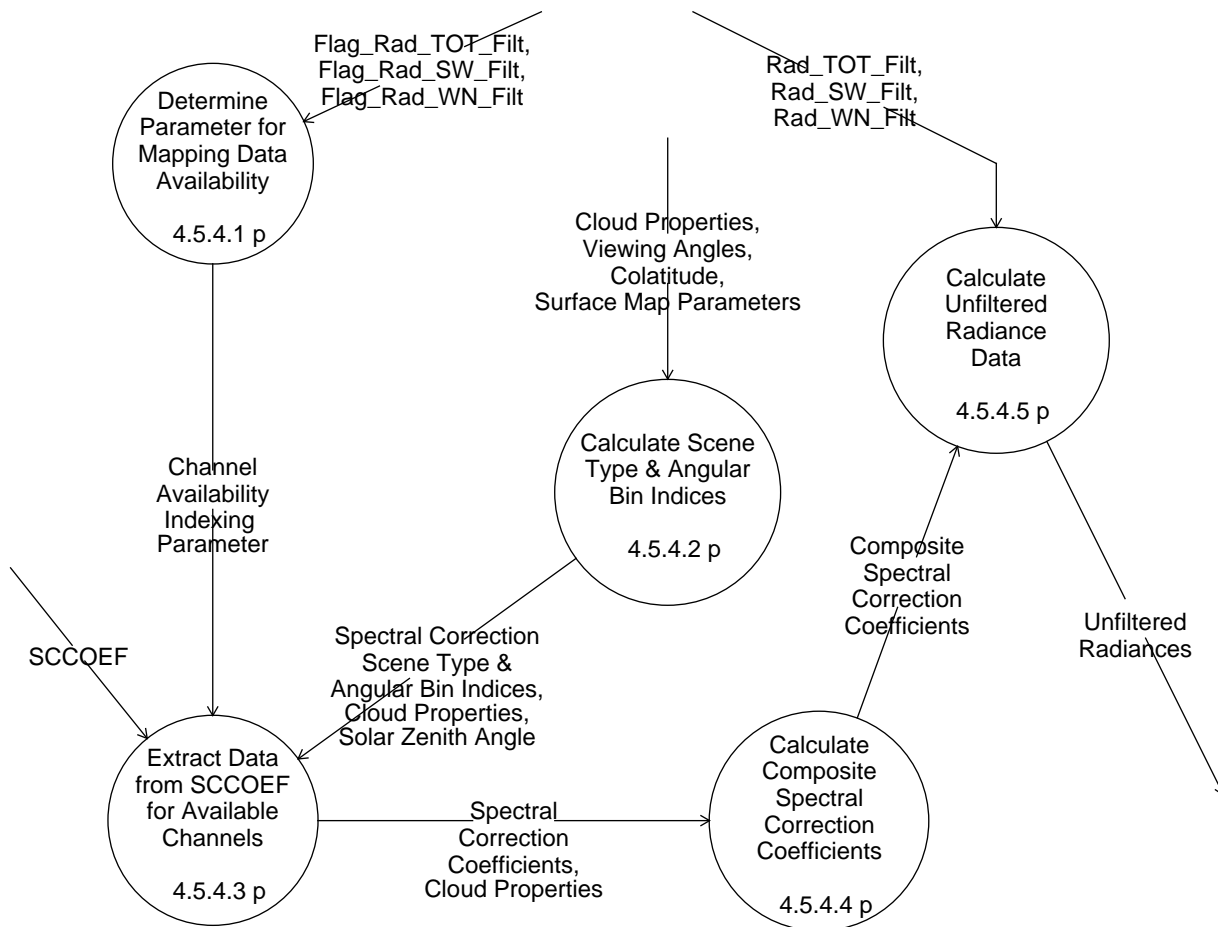The decomposition for this function is shown in Figure 5-4.

Figure 5-4. Data Flow Diagram for Apply_Spectral_Correction_Algorithm

5.2.1.4.1 Determine Parameter for Mapping Data Availability - Process 4.5.4.1

Input Data Flows
> Flag Rad SW Filt
> Flag Rad TOT Filt
> Flag Rad WN Filt

Output Data Flows
> Channel Availability Indexing Parameter

Process Specification (Figure 5-4):

This process will determine an indexing parameter for mapping the availability of filtered data from the SW, TOT, and WN channels into a spectral correction coefficient selection array. This process is required to perform the following steps:

- Set a counter for the number of valid scanner channels.
- Sum the valid channel indices.
- Calculate the indexing parameter used in mapping the availability of channel data by multiplying the number of valid scanner channels times the sum of the valid channel indices.

5.2.1.4.2 Calculate Scene Type & Angular Bin Indices - Process 4.5.4.2

Input Data Flows
> Cloud Properties
> Colatitude
> Surface Map Parameters
> Viewing Angles

Output Data Flows
> Cloud Properties
> Solar Zenith Angle
> Spectral Correction Scene Type & Angular Bin Indices

Process Specification (Figure 5-4):

This process is required to perform the following steps:

- Select the Spectral Correction Scene Type index based on the spectral correction scene and the colatitudinal zone of the footprint as shown in Table 5-3.
- Determine the satellite geometry angular bins for the viewing zenith angle, the solar zenith angle, and the relative azimuth angles.
- Determine the indices for the spectral correction coefficient arrays, based on the satellite geometry angular bin numbers and Spectral Correction Scene Type index.

Table 5-3. Spectral Correction Scene Types

Scene Type	Colatitudinal Zone	Scene
1	Tropical	Ocean
2	Mid-latitudinal	Ocean
3	Polar	Ocean
4	Tropical	Land
5	Mid-latitudinal	Land
6	Polar	Land
7	Tropical	Clouds
8	Mid-latitudinal	Clouds
9	Polar	Clouds
10	Tropical or Mid-latitudinal	Snow
11	Polar	Snow
12	Tropical or Mid-latitudinal	Desert

5.2.1.4.3 Extract Data from SCCOEF for Available Channels - Process 4.5.4.3

Input Data Flows
>Channel Availability Indexing Parameter
>Cloud Properties
>SCCOEF
>Solar Zenith Angle
>Spectral Correction Scene Type & Angular Bin Indices

Output Data Flows
>Cloud Properties
>Spectral Correction Coefficients

Process Specification (Figure 5-4):

This process is required to select sets of spectral correction coefficients based on daytime or nighttime coverage, Spectral Correction Scene Type, and channel data availability, using the following algorithm:

> Determine if the footprint is classified as daytime or nighttime by comparing the solar zenith angle to a predefined maximum solar zenith angle for daytime.
> If daytime
> Then Extract the daytime spectral correction coefficient set for overcast cloud cover
> > If the geoscene is coastal
> > Then Extract the daytime spectral correction coefficient set for ocean
> > > Extract the daytime spectral correction coefficient set for land
> > Else Extract the daytime spectral correction coefficient set for the scene type
> > End if
> Else (nighttime)
> > Extract the nighttime spectral correction coefficient set for overcast cloud cover
> > If geoscene is coastal
> > Then Extract the nighttime spectral correction coefficient set for ocean
> > > Extract the nighttime spectral correction coefficient set for land
> > Else Extract the nighttime spectral correction coefficient set for the scene type
> > End if
> End if

5.2.1.4.4 Calculate Composite Spectral Correction Coefficients - Process 4.5.4.4

Input Data Flows
> Cloud Properties
> Spectral Correction Coefficients

Output Data Flows
> Composite Spectral Correction Coefficients

Process Specification (Figure 5-4):

This process is required to perform the following steps:

- If the scene type covers both land and ocean, calculate the spectral correction coefficients for the Spectral Correction Scene Type by averaging the coefficients for land and the coefficients for ocean.
- Calculate the composite spectral correction coefficients from two sets of coefficients using a cloud cover weighting factor. One set of coefficients is based on Spectral Correction Scene Type and the other is based on overcast cloud conditions.

5.2.1.4.5 Calculate Unfiltered Radiance Data - Process 4.5.4.5

Input Data Flows
        Composite Spectral Correction Coefficients
        Rad SW Filt
        Rad TOT Filt
        Rad WN Filt

Output Data Flows
        Unfiltered Radiances

Process Specification (Figure 5-4):

This process is required to perform the following steps (see Reference 7):

- Calculate an estimate of the LW, SW and WN unfiltered radiance measurements using the filtered radiometric data and composite spectral correction coefficients. The unfiltered measurements, m^{SW}, m^{LW}, and m^{WN} are defined as

$$m^{LW} = A_c^{LW} m_f^{SW} + B_c^{LW} m_f^{TOT} + C_c^{LW} m_f^{WN}$$

$$m^{SW} = A_c^{SW} m_f^{SW} + B_c^{SW} m_f^{TOT} + C_c^{SW} m_f^{WN}$$

and

$$m^{WN} = A_c^{WN} m_f^{SW} + B_c^{WN} m_f^{TOT} + C_c^{WN} m_f^{WN}$$

where A_c^{SW}, B_c^{SW}, C_c^{SW}, A_c^{LW}, B_c^{LW}, C_c^{LW}, A_c^{WN}, B_c^{WN}, and C_c^{WN} are composite spectral correction coefficients, and m_f^{SW}, m_f^{TOT}, and m_f^{WN} are the filtered scanner measurements.

- Perform a three-channel consistency check on the unfiltered data.

5.2.1.5 Invert Radiance Data - Process 4.5.5

Input Data Flows
Scene Types
LW and SW ADM Values
Unfiltered Radiances

Output Data Flows
Scene Types
TOA Estimates
TOA Flux QC Report Data

Process Specification (Figure 5-2):

This process will estimate the radiant flux at the TOA for SW, LW, and WN radiances using the following equation:

$$M = \pi \, m \, / R$$

where:

M is the estimate of the radiant flux at the TOA,
m is the unfiltered radiance data at satellite altitude,
R is the ADM value

5.2.2 Determine Surface Fluxes and Finalize Process - Process 4.6

Input Data Flows
MOA
QC Report Data
SSF Data

Output Data Flows
SSF
SSFMETA
TSFQC

Process Description (Figure 5-1):

This process decomposes into:

- Calculate Surface Fluxes - Process 4.6.1
- Produce TOA and Surface Flux Products, Process 4.6.2

The decomposition of this function is shown in Figure 5-5.
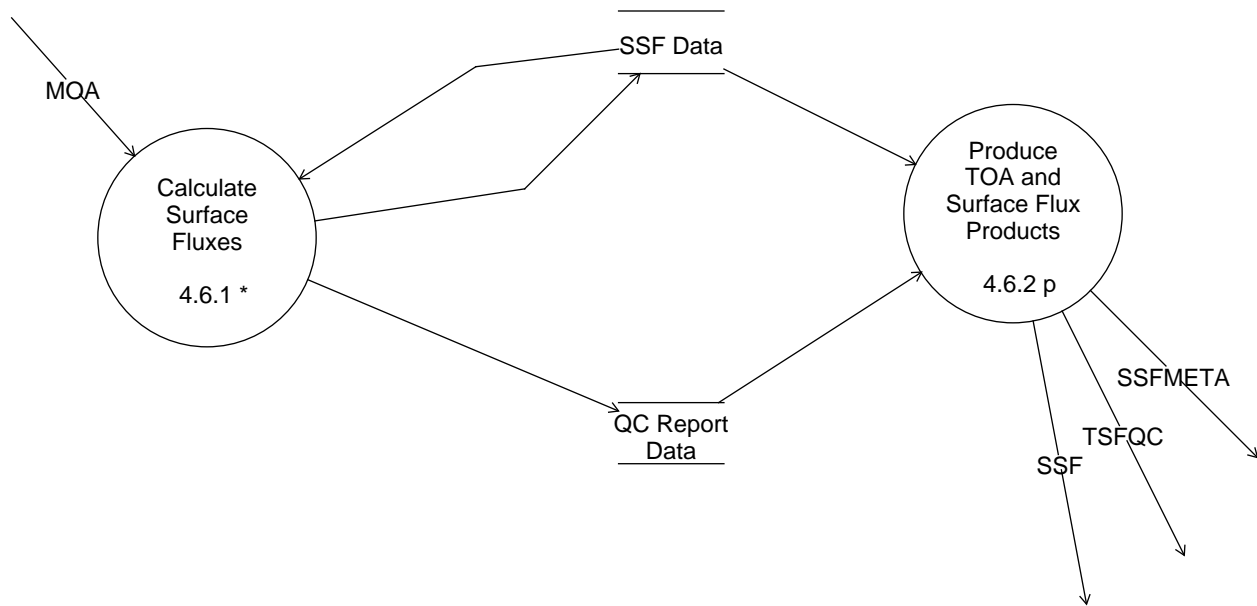
Figure 5-5. Data Flow Diagram for Determine_Surface_Fluxes_and_Finalize_Process

5.2.2.1 Calculate Surface Fluxes - Process 4.6.1

Input Data Flows
        MOA
        SSF Data

Output Data Flows
        QC Report Data
        SSF Data

Process Description (Figure 5-5):

This process will produce the SW and LW flux components of the surface radiation budget for a CERES footprint.   The input to this process will consist of CERES footprint cloud properties, CERES TOA fluxes for each footprint, and meteorological data. For Release 1, three algorithms have been defined.   The Li-Leighton algorithm (see References 2 and 10) will be used to estimate the SW net surface flux. The relationships derived by Inamdar and Ramanathan (see References 2 and 11) will be used to estimate the clear-sky LW downward and net surface fluxes over ocean.

The algorithm derived by Gupta et al. (see References 2 and 12) will be used to estimate the cloudy-sky LW downward and net surface fluxes and the clear-sky LW downward and net surface fluxes for footprints which are not over ocean or for which LW or WN TOA fluxes are not available (see Figure 5-6). The algorithm which estimates the downward SW flux at the Earth's surface is undefined at this time. This process decomposes into the following subprocesses:

- Read Input and Select Surface Algorithms, Process 4.6.1.1
- Estimate SW Net Flux at Surface, Process 4.6.1.2
- Estimate Clear-Sky LW Downward and Net Surface Fluxes over Ocean, Process 4.6.1.3
- Estimate LW Downward and Net Surface Fluxes, Process 4.6.1.4
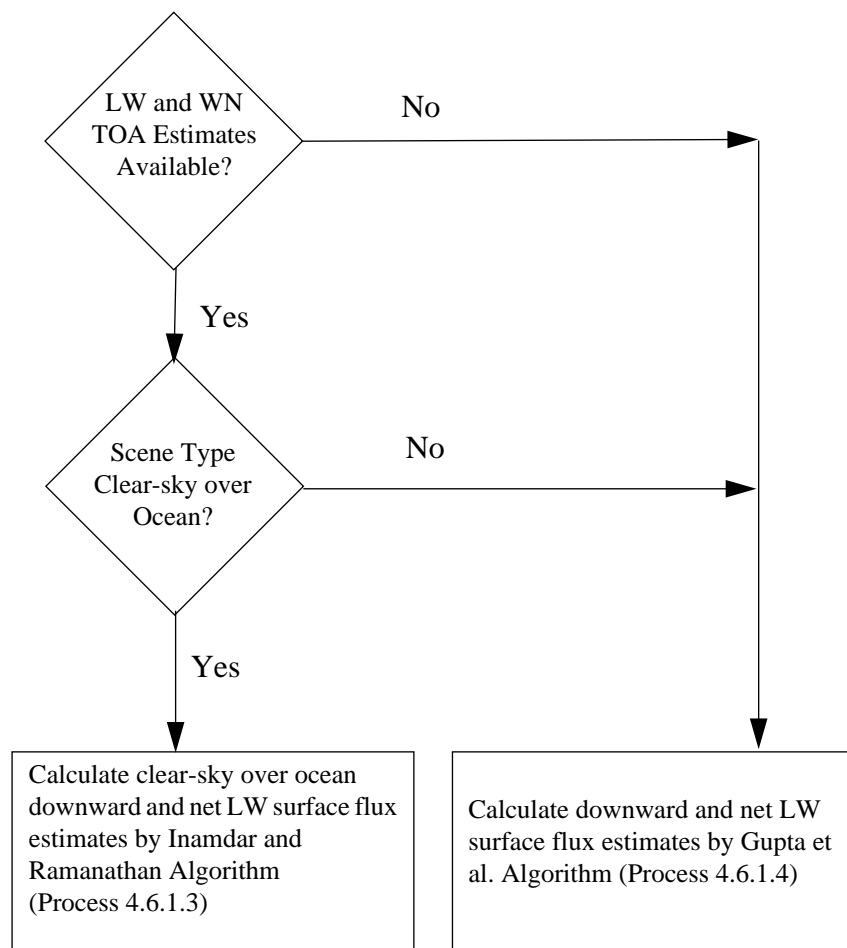
The decomposition of this function is shown in Figure 5-7.

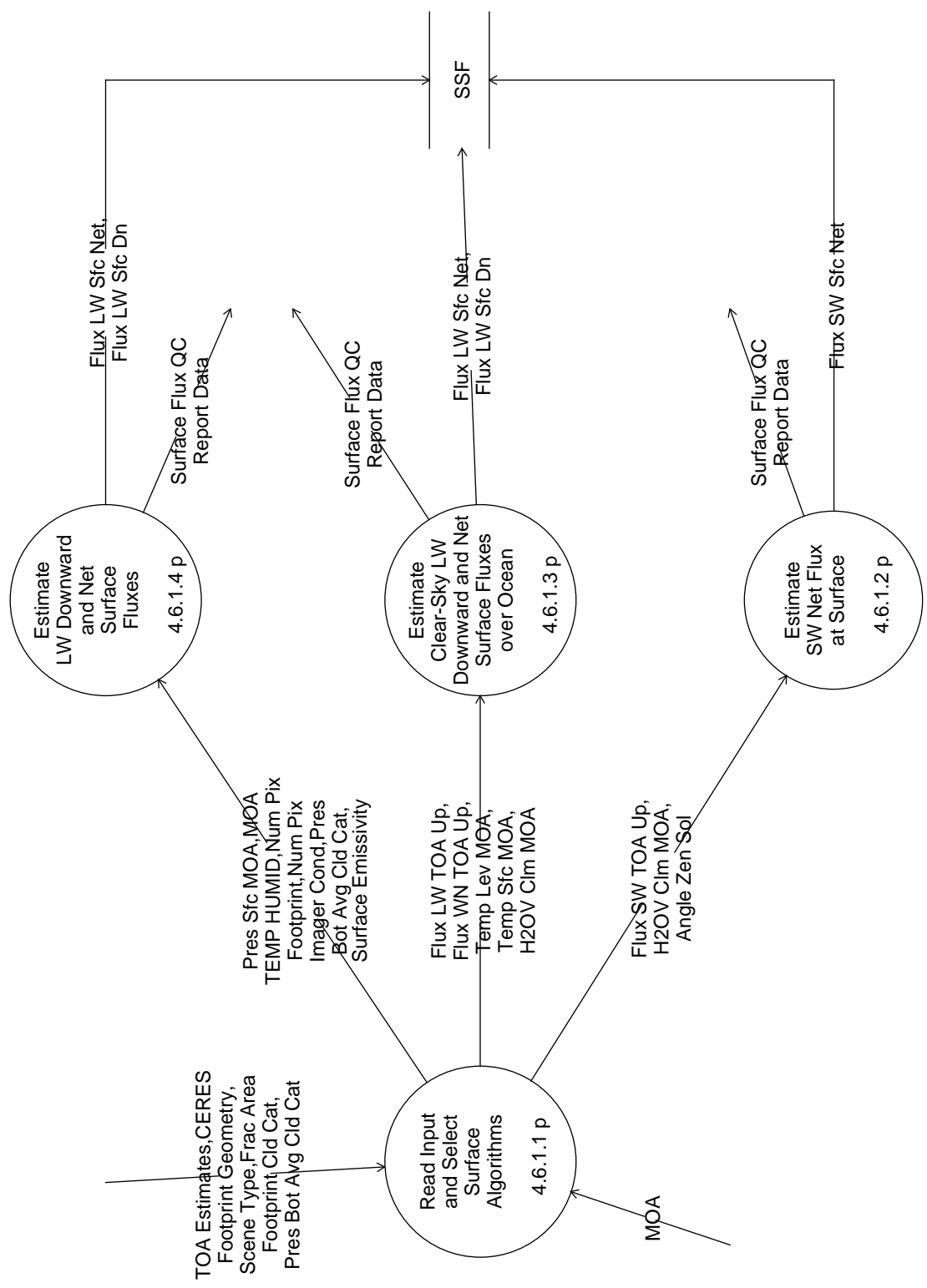Figure 5-6. Decision Tree for LW Downward and Net Surface Flux Estimates

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Figure 5-7. Data Flow Diagram for Determine_Surface_Fluxes

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5.2.2.1.1 Read Input and Select Surface Algorithms - Process 4.6.1.1

Input Data Flows
      CERES Footprint Geometry
      Frac Area Footprint Cld Cat
      MOA
      Pres Bot Avg Cld Cat
      Scene Type
      TOA Estimates

Output Data Flows
      Angle Zen Sol
      Flux LW TOA Up
      Flux SW TOA Up
      Flux WN TOA Up
      H2OV Clm MOA
      MOA TEMP HUMID
      Num Pix Footprint
      Num Pix Imager Cond
      Pres Bot Avg Cld Cat
      Pres Sfc MOA
      Temp Lev MOA
      Temp Sfc MOA

Process Specification (Figure 5-7):

This process will determine the availability of SW, LW, and WN TOA fluxes and the surface type of the CERES footprint. A SDP Toolkit call will request Meteorological, Ozone, and Aerosol (MOA) data for the time of observation (specific to the hour) and the colatitude and longitude at the surface, as defined in the CERES Instrument Earth Scans (IES) product (see Reference 13), for each footprint.   If the SW TOA estimate for the footprint is available, then the process which estimates the SW net surface flux will be initiated. The algorithm which estimates the downward SW flux at the Earth's surface is undefined at this time.   If the LW and WN TOA estimates for a CERES footprint are available and scene type is clear-sky over ocean, then the clear-sky downward and net LW surface flux estimates will be derived using the Inamdar and Ramanathan algorithm. If these conditions are not met, then the LW downward and net flux at the Earth's surface will be estimated using the algorithm derived by Gupta et al. A default (place holding) value for any surface flux parameter on the CERES footprint for which an estimation has not been derived will be written to the SSF data store.

5.2.2.1.2 Estimate SW Net Flux at Surface - Process 4.6.1.2

Input Data Flows
　　　Angle Zen Sol
　　　Flux SW TOA Up
　　　H2OV Clm MOA

Output Data Flows
　　　Flux SW Sfc Net
　　　Surface Flux QC Report Data

Process Specification (Figure 5-7):

This process will derive the net SW flux in W m^{-2} using the following equation (see References 2 and 10):

$$SW_{surf}^{net} = E_0 d^{-2}\mu \left\{ 1 - \frac{C}{\mu} - \frac{D}{\sqrt{\mu}} + \frac{1 + \exp(-\mu)}{\mu}(0.0699 - 0.0683\sqrt{p}) \right.$$

$$\left. - [\; 1 + A + B\ln(\mu) - 0.0273 + 0.0216\sqrt{p}\;]\, a_{TOA} \right\}$$

where:

　　　E_0 = solar constant = 1365 W m^{-2}

　　　d = Earth-sun distance in astronomical units

　　　p = precipitable water in gm cm^{-2}

　　　$\mu = \cos\theta_0$

　　　θ_0 = solar zenith angle

　　　a_{TOA} = albedo at TOA = $\dfrac{F_{TOA}}{E_0 d^{-2}\mu}$

　　　F_{TOA} = reflected SW flux at TOA, W m^{-2}

　　　$A = 0.0815$

　　　$B = 0.0139$

　　　$C = -0.01124$

　　　$D = 0.1487$

5.2.2.1.3 Estimate Clear-Sky LW Downward and Net Surface Fluxes over Ocean - Process 4.6.1.3

Input Data Flows
　　　Flux LW TOA Up

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Flux WN TOA Up
H2OV Clm MOA
Temp Lev MOA
Temp Sfc MOA

Output Data Flows
Flux LW Sfc Dn
Flux LW Sfc Net
Surface Flux QC Report Data

Process Specification (Figure 5-7):

1. The downward LW surface flux for a CERES footprint with scene type clear-sky over ocean will be derived using the following algorithm (References 2 and 11):

$$F_d^{clr} = \left[A_1^{reg} V + A_2^{reg} V^2 + A_3^{reg} V^3 + A_4^{reg} V^4 + B_1^{reg} g_a^{LW} + B_2^{reg} \ln\left(g_a^{Wn} \right) \right. $$
$$\left. + B_3^{reg} (T_s - T_{950}) \right] F_{TOA}^{LW} + B_4^{reg} F_b$$

where:

F_d^{clr} is the clear-sky downward LW surface flux

F_{TOA}^{LW} is the LW flux at the TOA in W m^{-2}

$F_b = \sigma T_s^4$, Surface blackbody emission

$g_a^{LW} = 1 - \dfrac{F_{TOA}^{LW}}{F_b}$ Normalized clear-sky greenhouse effect of the atmosphere (LW)

$g_a^{Wn} = \dfrac{F_b^{Wn} - F_{TOA}^{Wn}}{F_b}$ Normalized clear-sky greenhouse effect of the atmosphere (WN)

F_b^{Wn} is the Planck blackbody function integrated from 8 to 12 microns

F_{TOA}^{Wn} is the WN flux at the TOA in W m^{-2}

$V = \ln W$
W is the total column precipitable water in cm
T_{950} is the temperature of the atmosphere at pressure
    level 950 mb
T_s is the surface temperature

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σ is the Stefan-Boltzman constant

A_i^{reg} are the regression coefficients for terms containing variable, V

B_i^{reg} are the regression coefficients for terms which depend on variable, T_s

Note: A_i^{reg} and B_i^{reg} are defined below:

$$A_1^T = 0.06079$$

$$A_2^T = 0.11333$$

$$A_3^T = -0.04981$$

$$A_4^T = 0.01041$$

$$B_1^T = 1.04623$$

$$B_2^T = -0.03783$$

$$B_3^T = -0.00616$$

$$B_4^T = 0.43653$$

$$A_1^{ET} = 0.10910$$

$$A_2^{ET} = 0.04496$$

$$A_3^{ET} = 0.01308$$

$$A_4^{ET} = -0.00134$$

$$B_1^{ET} = 1.39348$$

$$B_2^{ET} = -0.12229$$

$$B_3^{ET} = -0.00294$$

$$B_4^{ET} = 0.13854$$

where
$$reg = \begin{cases} \text{T for Tropics } (60° < \text{Colat Sfc} < 120°) \\ \text{ET for Extra Tropics } (60° \geq \text{Colat Sfc or} \\ \qquad\qquad\qquad\qquad \text{Colat Sfc} \geq 120°) \end{cases}$$

$$i \quad = 1, 2, 3, 4$$

2. The net LW radiative flux at the Earth's surface for clear-sky, F_n^{Clr}, is derived using the following algorithm (Reference 2):

$$F_n^{Clr} = F_d^{Clr} - \sigma T_s^{\,4}$$

5.2.2.1.4 Estimate LW Downward and Net Surface Fluxes - Process 4.6.1.4

Input Data Flows
      MOA TEMP HUMID
      Num Pix Footprint
      Num Pix Imager Cond
      Pres Bot Avg Cld Cat
      Pres Sfc MOA
      Surface Emissivity (source TBD)

Output Data Flows
      Flux LW Sfc Dn
      Flux LW Sfc Net
      Surface Flux QC Report Data

Process Specification (Figure 5-7):

1. The downward LW radiative flux at the Earth's surface (for a CERES footprint which does not have scene type clear-sky over ocean or for which the LW or WN TOA flux is not available) will be derived using the following algorithm (References 2 and 12):

$$F_d = C^{Clr} + \sum_{i=1}^{4} C_i^{Cld} A_i^{Cld}$$

where:
      F_d is the all-sky downward LW flux at the surface
      C^{Clr} is the clear-sky downward LW flux at the surface

$$C^{Clr} = \left(A_0 + A_1 V + A_2 V^2 + A_3 V^3 \right) \times T_e^{\,3.7}$$

where:
      $V = \ln W'$
      W is the total column precipitable water in cm
      W' is the water vapor burden of the atmosphere in kg m^{-2}
      $W' = W / 10$
      T_e is the effective emitting temperature of the atmosphere
      $T_e = k_s T_s + k_1 T_1 + k_2 T_2$
      T_s is the surface temperature
where:

The weighting factors for effective emitting temperature of the atmosphere are

$k_s = 0.60$
$k_1 = 0.35$
$k_2 = 0.05$

Note: The weighting factor values, k_s, k_1, k_2, are dependent on the layer structure of the atmosphere and will change with the layer structure.

T_1 is the mean temperature of the 1st atmospheric layer next to the surface.
T_2 is the mean temperature of the 2nd atmospheric layer next to the surface.

Note: In the present scheme, the layer structure of the atmosphere is as shown in Table 5-4.

Table 5-4. Layer Structure of the Atmosphere

Layer Number	Layer Structure
1st layer, l_1	surface $\geq l_1 > 800$ hPa
2nd layer, l_2	$800 \geq l_2 > 680$ hPa
3rd layer, l_3	$680 \geq l_3 > 560$ hPa

The extent of the 1st and 2nd layer next to the surface depends on the surface pressure.

The regression coefficients for calculating clear-sky downward LW flux are

$A_0 = 1.791 \times 10^{-7}$
$A_1 = 2.093 \times 10^{-8}$
$A_2 = -2.748 \times 10^{-9}$
$A_3 = 1.184 \times 10^{-9}$

For each of the 4 cloud layer categories:
Note: The cloud layer categories as shown in Table 5-5 are different from the atmospheric layers used in calculating the clear-sky LW surface flux as shown in Table 5-4.

Table 5-5. Cloud Layer Categories

Cloud Layer Number, i	Cloud Height Category	Effective* Cloud Pressure, p_e, Range
1	High Cloud	$p_e \leq 300$ hPa
2	Upper Middle Cloud	$300 < p_e \leq 500$ hPa
3	Lower Middle Cloud	$500 < p_e \leq 700$ hPa
4	Low	$700 < p_e \leq 1000$ hPa

A_i^{Cld} is the weighted area fraction for cloud layer category i

Note: If the scene type is clear-sky, then A_i^{Cld} is equal to 0
for each of the 4 cloud layer categories

C_i^{Cld} is the cloud forcing factor for cloud layer category i

For $\left(P_s - P_i^{cb} \right) > 200$ hPa, the cloud forcing factor is represented as:

$$ C_i^{Cld} = \left(T_i^{cb} \right)^4 / \left(B_o + B_1 W_i^{cb} + B_2 \left(W_i^{cb} \right)^2 + B_3 \left(W_i^{cb} \right)^3 \right) $$

where:

P_s is the surface pressure.

P_i^{cb} is the mean cloud base pressure for cloud layer category i.

T_i^{cb} is the cloud base temperature for cloud layer category i. T_i^{cb} will be obtained by matching P_i^{cb} against the available temperature profile.

W_i^{cb} is the water vapor burden below the cloud base for cloud layer category i, in kg m^{-2}

The regression coefficients for calculating the cloud forcing factor are

$B_0 = 4.990 \times 10^7$

$B_1 = 2.688 \times 10^6$

$B_2 = -6.147 \times 10^3$

$B_3 = 8.163 \times 10^3$

For $\left(P_s - P_i^{cb} \right) = 0$, the cloud forcing factor is represented as:

$$C^{Cld} \;=\; C_{max}^{Cld} \;=\; \sigma T_s^4 - C^{Clr}$$

and

$$F_d \;=\; \sigma\left(T_i^{cb} \right)^4$$

Note: C_{max}^{Cld} is the maximum value of C_i^{Cld} , which occurs when the cloud
base is at the surface.

For $0 < \left(P_s - P_i^{cb} \right) \le 200$, the cloud forcing factor is represented as:

$$C_i^{Cld} \;=\; \left(T_i^{cb} \right)^4 \bigg/ \left(B_0'' + B_1 W_i^{cb} + B_2\left(W_i^{cb} \right)^2 + B_3\left(W_i^{cb} \right)^3 \right)$$

The applicable value of the regression coefficient, B_0'', is obtained by
linear interpolation (in pressure) between B_0 and B_0'.
where:

$$B_0' \;=\; T_s^4 \bigg/ \left(\sigma T_s^4 - C^{Clr} \right)$$

2. The net LW radiative fluxes at the Earth's surface are derived using the following
   algorithm:

$$F_n \;=\; F_d - \varepsilon_s \sigma T_s^{\,4} - (1 - \varepsilon_s) F_d$$

where:

ε_s	is the emissivity of the surface
F_n	is the net LW flux at the surface
σ	is the Stefan-Boltzman constant
T_s	is the surface temperature

5.2.2.2 Produce TOA and Surface Flux Products - Process 4.6.2

Input Data Flows
>   SSF Data
>   QC Report Data

Output Data Flows
    SSF
    SSFMETA
    TSFQC

Process Specification (Figure 5-5):

This process is required to perform the following steps:

- Write the final SSF product, using the SDP Toolkit call for writing HDF files
- Write the TOA & Surface Flux QC Report, TSFQC
- Write the SSF metadata file, SSFMETA, using the SDP Toolkit

5.3 Design Goals and Constraints

The following are considered to be the design constraints for this subsystem:

1. ERBE ADMs will be replaced with CERES ADMS in Release 3.
2. Additional CERES inversion scene types will be added when the CERES ADMs replace the ERBE ADMs.
3. Surface radiation budget algorithms may be modified or replaced in future releases.
4. The format and parameter content of metadata will be determined by ECS and will be generated using the SDP Toolkit (see Reference 6).
5. SDP Toolkit calls will be used wherever possible.

Based on these constraints, the design goals for this Subsystem include:

1. The software will be designed in a way which will allow the algorithms which estimate the surface radiative fluxes to be easily replaced or modified.

2. Coefficients and other known constants that may be changed during algorithm revisions will be defined in a location in the software where the modifications can easily be made.

5.4 Resource Use

The estimated size of an SSF product is 154 megabytes.   There will be 24 hourly SSF Products per day, which will require a daily total of approximately 4 gigabytes of storage space per CERES instrument.

The estimate for the processing load requirements for Subsystems 4.5 and 4.6 on a SPARC 2 running at 4 million floating point operations per second (MFLOPS) is approximately 2800 seconds of CPU time and 50 minutes of wall time per day. These estimates are based on direct measurements from the execution of the ERBE inversion and CERES ERBE-like inversion algorithms.

References

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Abbreviations, Acronyms, and Symbols

ADM	Angular Distribution Models
ASTR	Atmospheric Structures
ATBD	Algorithm Theoretical Basis Document
AVHRR	Advanced Very High Resolution Radiometer
cm	centimeters
CADM	CERES Angular Distribution Models
CERES	Clouds and Earth Radiant Energy System
ECS	EOSDIS Core System
EOS	Earth Observing System
EOS-AM	EOS Morning Crossing Mission
EOSDIS	EOS Data Information System
EOS-PM	EOS Afternoon Crossing Mission
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
FOV	Field of View
gm cm^{-2}	grams per square centimeter
HIRS	High Resolution Infrared Radiation Sounder
HDF	Hierarchical Data Format
hPa	hectoPascal
IES	Instrument Earth Scans
kg m^{-2}	kilograms per square meter
LW	Longwave
μm	micrometers
MFLOPS	Million Floating Point Operations per Second
MOA	Meteorological, Ozone, and Aerosol
MODIS	Moderate-Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
PSF	Point Spread Function
RAPS	Rotating Azimuth Plane Scan
QC	Quality Control
SAGE	Stratosphere Aerosol and Gas Experiment
SARB	Surface and Atmospheric Radiation Budget
SCCOEF	Spectral Correction Coefficient Data
SDP	Science Data Production
SRD	Software Requirements Document
SSF	Single Satellite CERES Footprint TOA and Surface Fluxes, Clouds
SSFMETA	SSF Metadata
SW	Shortwave
TOA	Top-of-atmosphere
TOT	Total
TRMM	Tropical Rainfall Measuring Mission

TSFPARAM	TOA and Surface Flux Parameter Data
TSFQC	TOA and Surface Flux Quality Control Report
W m^{-2}	Watts per square meter
WN	Window