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

Data Management System

Software Requirements Document

Regrid Humidity and Temperature Fields
(Subsystem 12.0)

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

The CERES Regrid Humidity and Temperature Fields Subsystem will ingest meteorological, ozone, and aerosol data from several different external sources and combine these data into one file, the Meteorological, Ozone, and Aerosol (MOA) file. The MOA will be an hourly file, spatially organized according to a 1.25-deg equal-area grid, conforming to CERES requirements. Since the input data from the different external sources do not conform to a common spatial and temporal grid system, this Subsystem will spatially and temporally interpolate the input data to conform with CERES standards. Software developed by the CERES, Clouds, Surface and Atmospheric Radiation Budget (SARB), and Time Interpolation and Spatial Averaging (TISA) Working Groups will all require access to the data contained in the MOA.

The EOS Data and Information System (EOSDIS) Core System (ECS) is responsible for obtaining the external ancillary input data required by this Subsystem. EOSDIS will perform the initial ingestion of these data and store them in an easily accessible format. The spatial and temporal resolutions of these data will not be altered. Once EOSDIS has performed the initial ingestion, the data will be made available to the various EOS projects, including CERES. EOSDIS will provide a scheduler that will track the availability of these input data sets and subsequently control processing of Product Generation Executables (PGE) such as the Regrid Humidity and Temperature Fields Subsystem. The CERES Science Team will decide on an allowable lag time between the measurement of CERES data and the execution of this Subsystem. This lag time should be built into the EOSDIS processing scheduler, and should allow for the accumulation of the necessary input data from the external sources. If all of the necessary data are not available from the external sources after this lag time, the Regrid Humidity and Temperature Fields Subsystem may access a climatology approved by the CERES Science Team.

This Subsystem will first interpolate the input data horizontally, which is the domain where the data have the smallest variability. Next, the data will be temporally interpolated. Lastly, the data will be interpolated in the vertical domain, where the data have the largest variability. Not every parameter will need to be interpolated in all three domains. Which interpolations are needed for which parameters will be discussed in the appropriate sections of this document.

The external products that Subsystem 12 will access are the Aerosol Product (APD), the Gridded Analysis Product (GAP), the Microwave Humidity (MWH) Product, and the Ozone Profile and Column Data (OPD). Since different aerosol data from multiple sources is desirable, the APD product may actually consist of multiple files. The same is true for the GAP and the OPD. These input data products will include temperature and humidity profiles, surface temperature and pressure, microwave derived precipitable water, column aerosol and ozone data, and stratospheric aerosol and ozone data. These data may come from the National Meteorological Center (NMC), other instruments flying concurrently with CERES such as the Moderate Resolution Imaging Spectrometer (MODIS), or from climatology selected by the CERES Science Team. Also required as input are other data defined prior to processing, such as the Processing and Control Parameters for Subsystem 12 (PCP12).

The MOA file, the primary output product from the Regrid Humidity and Temperature Fields Subsystem, will include the same meteorological data as the input products, except on a common temporal and spatial grid system as previously specified. Also required to be output, is the Quality Control Report for Subsystem 12 (QC12) that displays run-time statistics, along with a file of metadata, META12, required by EOSDIS to be generated by each run of this Subsystem.

The input and output products for the Regrid Humidity and Temperature Fields Subsystem are described in Section 2.0. Requirements for the ingestion and interpolation of the input data are given in Section 3.0.

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

The overall approach taken to gather the requirements stated in this document include the use of Reference 1, information gleaned from attending meetings of the SARB Working Group, and from collaboration with members of this group.

2.0 External Interface Requirements

A context diagram indicating the input and output requirements of the Regrid Humidity and Temperature Fields Subsystem is shown in Figure 2-1. Input data required by this Subsystem include the temporally varying APD, GAP, OPD, and MWH files, along with data defined prior to processing, that are included in the PCP12 file. The primary output from this Subsystem is the MOA file. The required outputs also include the QC12 report that displays run-time statistics and the EOSDIS-required metadata file, META12.

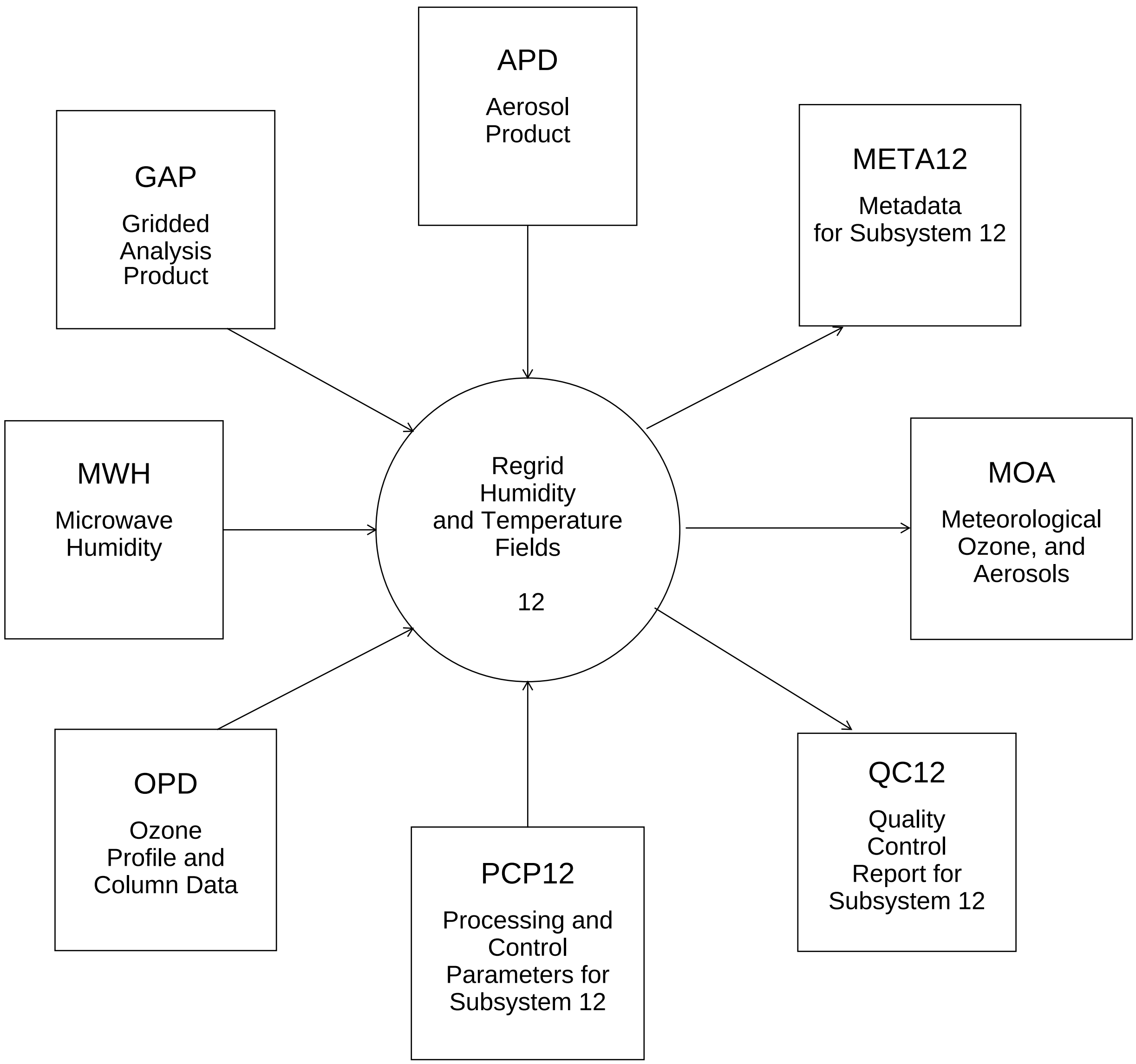

Figure 2-1. Context Diagram

2.1 Input Products

Since several of the data sources described in the following sections will not be available prior to a CERES launch, such as the data from the MODIS instrument, for Release 1 it is anticipated that the Regrid Humidity and Temperature Subsystem will use climatologies specified by the CERES Science Team. Even after launch, there may be periods of time for which data from an external source may not be available and these climatologies will be necessary. The CERES Science Team will indicate the largest allowable time gap between samples for each data source. Also, the sources of these data are not yet finalized. Until data from these instruments can be evaluated by the CERES Science Team, the data sources named in the following sections should be viewed only as examples of possible sources. These sources are mentioned only in an effort to prepare the developers of this Subsystem for the need to be flexible when developing software to ingest and process the input data.

While some of these sources may organize their data such that a single file contains data for the entire globe, other sources may organize their data according to what data were measured in a particular time frame, e.g. orbital swaths. It should be noted that not all sources of these external ancillary input data sets will be obtained from instruments flying in the same orbit as CERES.

The ECS plans to provide Toolkit routines for easy access to products such as the APD, GAP, MWH, and OPD. This toolkit will eliminate the CERES team from having to know and understand the structure of these files. Currently, the plan is to develop these tools such that, given the required parameter name, along with desired location and time, the Toolkit routine will retrieve the requested data. For the location, beginning and ending latitudinal and longitudinal coordinates may be used so that all requested data may be retrieved with one call to the routine. See Reference 2 for more information on these routines (specifically the routines PGS_AA_2DGEO, PGS_AA_2DRead, PGS_AA_3DGEO, and PGS_AA_3DRead).

2.1.1 Aerosol Product (APD)

The APD is the source of both total column aerosol data and stratospheric aerosol data. It will probably be composed of multiple files.

The total column aerosol data may be derived daily from the MODIS instrument for the EOS-AM and EOS-PM platforms. For TRMM, the total column aerosol data may be derived weekly from Advanced Very High-Resolution Radiometer (AVHRR) data. AVHRR data may also be used for the EOS-AM and EOS-PM platforms. MODIS data will have a horizontal resolution of either 50-km x 50-km or 5-km x 5-km for ocean, and 50-km x 50-km for nondesert land. AVHRR data have a horizontal resolution of one-deg longitude by one-deg latitude.

The stratospheric aerosol data may be derived monthly from either concurrent Stratospheric Aerosol and Gases Experiment (SAGE) data or a climatology based on SAGE data. The SAGE data have a horizontal resolution of 10-deg longitude by 10-deg latitude. Data from the Multi-Angle Imaging Spectro-Radiometer (MISR) instrument may be used as a backup source. MISR will provide full global coverage every 10 to 15 days.

2.1.2 Gridded Analysis Product (GAP)

The GAP contains vertical profiles of temperature, humidity, and geopotential height as a function of pressure, along with surface temperature and pressure. The GAP will probably be composed of multiple files.

It is anticipated that these data will be available every 6 hours from NMC on a 2.5-deg equal angle grid. It is also anticipated that by the launch of TRMM, NMC will be providing profile data for approximately 50 atmospheric levels. NMC may also provide land surface temperature, while the TRMM Microwave Imager (TMI) may provide sea surface temperature.

Data from the European Centre for the Medium Range Weather Forecasting (ECMWF) may be used in the unlikely event that data from NMC is not available (NMC has slated backup sources should their primary sources not be available).

2.1.3 Microwave Humidity (MWH) Product

The MWH is the source of the column precipitable water vapor burden as derived from a microwave instrument. These data may be derived daily from the Special Sensor Microwave/ Imager (SSM/I) instrument, which has a horizontal resolution of 16-km x 23-km. These data will only be available over ocean, and will not be available over ice clouds. If the column precipitable water vapor is not available from a microwave instrument, then the column precipitable water vapor may be calculated from the GAP humidity profile data.

2.1.4 Ozone Profile and Column Data (OPD)

The OPD is the source of both total column ozone data and stratospheric ozone data. The OPD will probably be composed of multiple files.

The total column ozone data may be derived daily from the Total Ozone Mapping Spectometer (TOMS) instrument. TOMS data are horizontally organized according to a 1.25-deg x 1.25-deg equal-angle grid.

The stratospheric ozone data may be derived monthly from either concurrent SAGE data or a climatology based on SAGE data, or derived weekly from a Solar Backscatter Ultraviolet Radiometer (SBUV) instrument, SBUV-2. SAGE and SBUV-2 data are horizontally organized according to a 10-deg longitude by 10-deg latitude grid.

Some CERES algorithms will require the vertical profile of ozone data, while other CERES algorithms will require the total column ozone. The vertical profile of ozone data will be derived from the stratospheric ozone data, as total column ozone data is not suitable for vertical profiling due to limitations of the instruments measuring the data.

2.1.5 Processing and Control Parameters for Subsystem 12 (PCP12)

Processing and Control Parameters contained in the PCP12 file, used by the Regrid Humidity and Temperature Fields Subsystem, are parameters that are defined prior to Subsystem processing and ingested by the Subsystem at run-time. Potential processing and control parameters known at this time for this Subsystem are listed in Table 2-1. This list will be expanded as more work on the design and actual coding takes place. The SARB Working Group, along with other members of the CERES Science Team, will supply the values of these parameters.

Table 2-1. Known Processing and Control Parameters

Parameter Description
Number of atmospheric levels at which to produce meteorological profiles output to the MOA file.
Pressure, in hPa, of the atmospheric levels represented in the meteorological profiles contained on the MOA file.
Number of atmospheric levels at which to produce ozone profile for the MOA file.
Pressure, in hPa, of the atmospheric levels contained in the ozone profile contained on the MOA file.
Ozone vertical profile weight factors (for each source of ozone data).
Largest distance for regions to be considered “nearest neighbors” for each external ancillary input data source for the horizontal interpolation processes.
Largest allowable time gap between sample times for each external ancillary input data source.
Limits for allowable input data value ranges.

2.2 Output Products

2.2.1 Metadata for Subsystem 12 (META12)

The contents of this product, a requirement of EOSDIS, are to be determined (TBD).

2.2.2 Meteorological, Ozone, and Aerosol (MOA)

The MOA, a CERES archival product, is produced by the CERES Regrid Humidity and Temperature Subsystem. Each MOA file contains meteorological, ozone, and aerosol data for one hour and is used by several of the CERES subsystems. Data on the MOA are derived from several data sources external to the CERES system, such as the NMC, 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 3.

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 2-2. It should be noted that prior to Release 2, the number of levels most likely will change from 38, and the levels themselves may also change.

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

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

2.2.3 Quality Control Report for Subsystem 12 (QC12)

The QC12 product will contain statistics accumulated during processing of the Regrid Humidity and Temperature Subsystem. The purpose of this product is to provide both Science Team and DMT members with a diagnostic report from which subsystem processing results can be reviewed. These reports will be stored electronically, and may be reviewed individually or with others as a tool to assist in the study of possible trends. While the exact contents of QC12 are TBD, they may include such things as processing time, the number of regions for which MOA data are produced, the number of occurrences of events such as out-of-range values, and averages of MOA data according to colatitudinal bins. As the design and coding take place, the SARB and Clouds Working Groups will indicate what values they would like to see displayed in this report.

3.0 Requirements Specification

This section provides the specification of requirements which must be satisfied by the DMT for the Regrid Humidity and Temperature Fields Subsystem. Included are operating modes, functional requirements, design goals and constraints, and resource use.

3.1 Operating Modes

The Regrid Humidity and Temperature Fields Subsystem will process in a production mode, beginning at the time of the launch of the first CERES instrument.

3.2 Functional Requirements

This section identifies the specific functional requirements of the Regrid Humidity and Temperature Fields Subsystem. These requirements are divided among various processes, the specifications for which are discussed in the sections that follow. A top-level context diagram was previously depicted in Figure 2-1. The first level of decomposition for this Subsystem is depicted in Figure 3-1. The processes depicted in this figure include Initialize Processing, Process APD Data, Process GAP Data, Process MWH Data, Process OPD Data, and Finalize Processing. Processes that can be further decomposed into subprocesses, such as Process 12.2, are indicated by the inclusion of an "*" in the diagram beside the process number. If there are no subprocesses, such as for Process 12.1, the diagram will include a "p" beside the process number. These process specifications will be used to define the testing requirements for the system at the time of the preparation of the system test procedures.

3.2.1 Initialize Processing - Process 12.1

Input Data Flows

PCP12

Output Data Flows

MOA Metadata
MOA Time

Process Specification:

Subsystem processing begins by ingesting any input data, such as processing and control parameters, that will be used throughout subsystem processing. Any parameters that need to be initialized, such as various counters and cumulative sums, need to be initialized here. Parameters requiring initialization are TBD but will become known as work progresses on the code design and development phases.

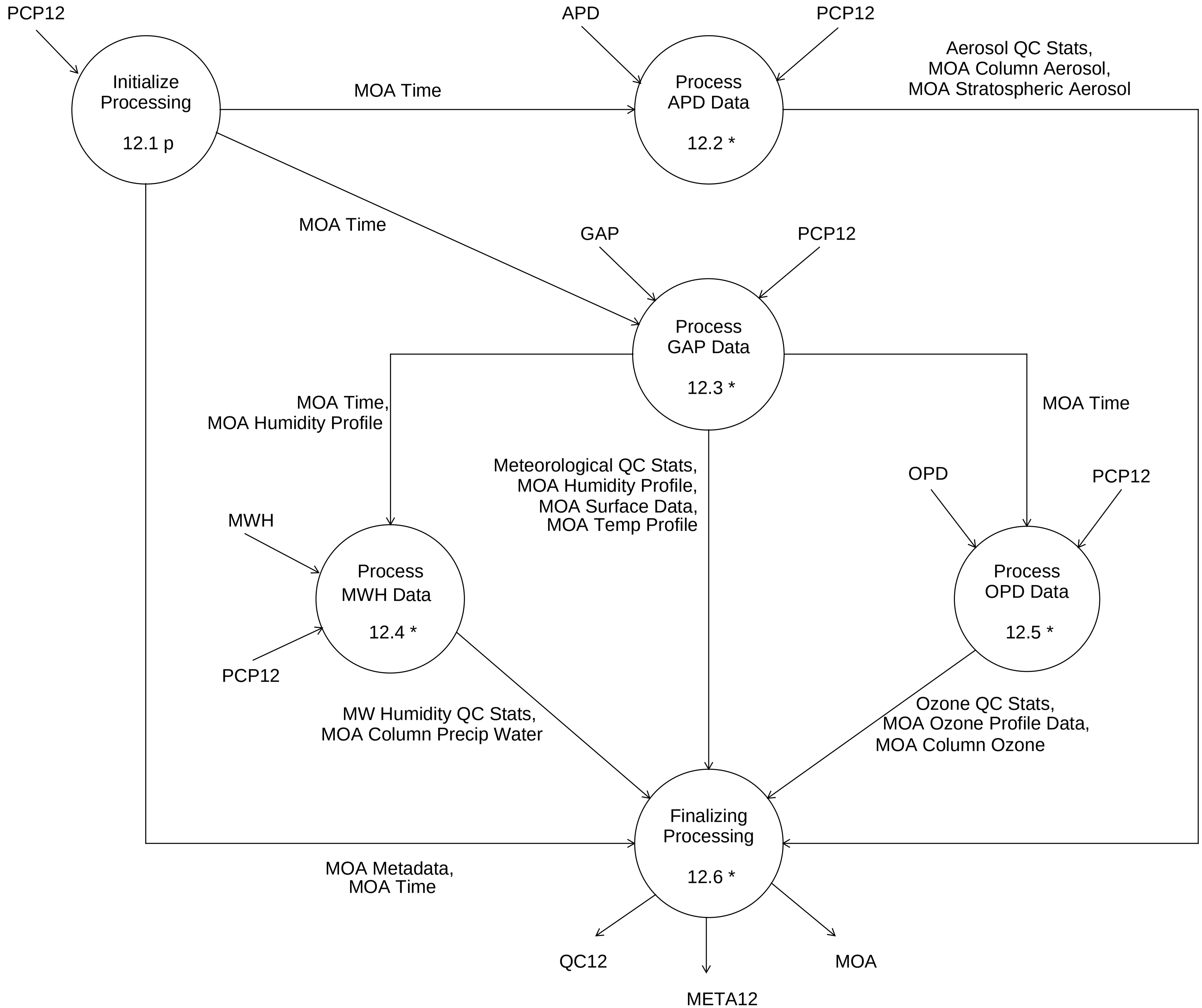

Figure 3-1. Data Flow Diagram for Level 0

The Regrid Humidity and Temperature Fields Subsystem must know for which time it is to generate the hourly MOA file. It is assumed that this information will be available to this Subsystem somehow via the EOSDIS scheduler.

To initialize processing, the following steps are required:

- Ingest processing and control parameters.
- Initialize required parameters.
- Determine requested MOA time from information provided by EOSDIS scheduler.

3.2.2 Process APD Data - Process 12.2

Input Data Flows

APD
MOA Time
PCP12

Output Data Flows

Aerosol QC Stats
MOA Column Aerosol
MOA Stratospheric Aerosol

APD data consists of stratospheric aerosol data and column aerosol data. After the ingestion of the APD data, both the column and the stratospheric data will be interpolated horizontally and temporally. Statistics for the QC12 report that pertain to the aerosol data will also be accumulated during this process. These subprocesses are depicted in Figure 3-2, and are discussed in Sections 3.2.2.1, 3.2.2.2, 3.2.2.3, and 3.2.2.4.

3.2.2.1 Ingest APD Data - Process 12.2.1

Input Data Flows

APD
MOA Time
PCP12

Output Data Flows

APD Column Aerosol
APD Stratospheric Aerosol

Process Specification

Since the Regrid Humidity and Temperature Fields Subsystem is required to generate a MOA product for every hour and the external ancillary input data are available less frequently, temporal interpolation is necessary. The PCP12 file will contain the maximum time gap between the time of the MOA file and the sampled time of the external ancillary input data. If this time gap is exceeded, then the climatology approved by the CERES Science Team will be used. This logic will be followed whether at the beginning, end, or middle of a month. This requirement means that except for MOA products that concur with an input data file's sample time, a second input data file must also be ingested.

For errors encountered during file openings and input/output operations, error messages need to be issued. The utility to issue such messages, along with the utility to terminate subsystem processing, may be provided by EOSDIS or the CERES Data Management Team. If so, these are the utilities to be used.

Should the input data be organized according to an orbital swath, the data will need to be ingested on a regional basis until data have been ingested for the entire globe. For each region, the time the data were measured will also be necessary for the temporal interpolation. If the data are organized according to a global grid, the data may be ingested on a global basis.

Ingestion of APD data requires the following steps:

- Using EOSDIS Toolkit routine, open most recent APD data file(s) containing stratospheric aerosol.
- If APD data for most recent allowable sample time is not available
    - Using EOSDIS Toolkit routine, open approved climatology files.

  End If
- Set data source flag to indicate source of stratospheric aerosol data.
- Using EOSDIS Toolkit routine, read most recent stratospheric aerosol data and associated sample time for each region.
- If read errors are encountered
    - Invoke message utility.
    - Terminate subsystem processing.

  End If
- If current MOA hour does not match stratospheric aerosol sample time
    - Following the previously stated requirements for ingesting the most recent APD product (with the exception of setting the source flag), ingest next chronological APD product.

  End If
- Repeat ingestion process for column aerosol (most recent and next chronological files).

Please note that the background information and required steps given in this section are also applicable to the ingestion processes of other external ancillary input data for this Subsystem.

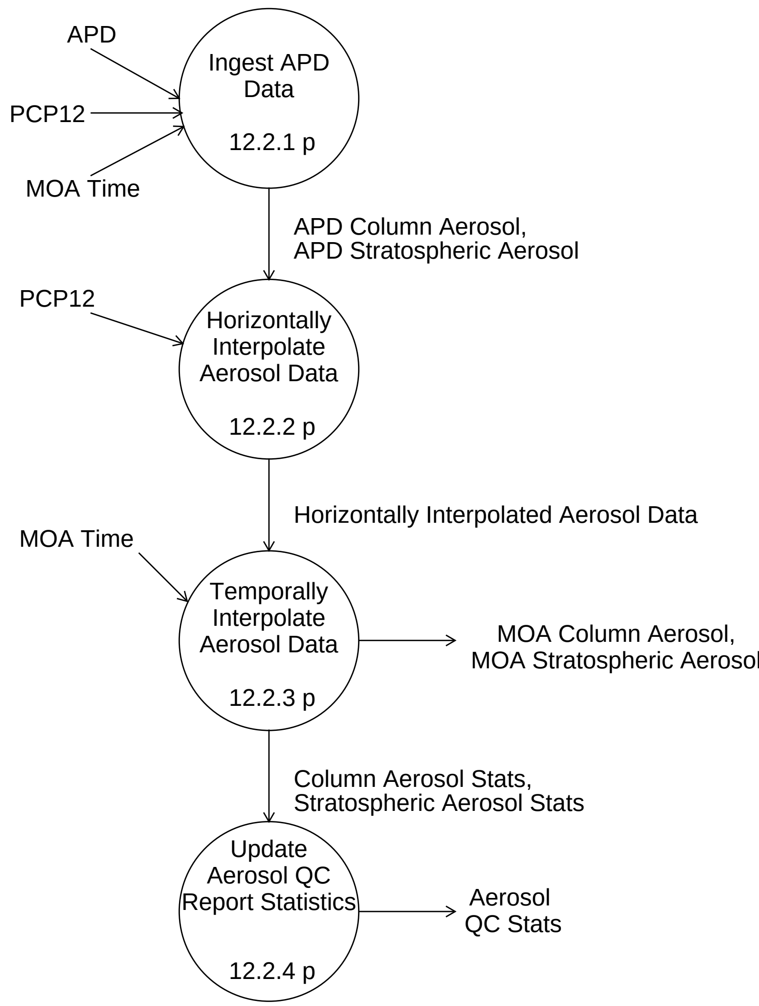

Figure 3-2. Data Flow Diagram for Process APD Data

3.2.2.2 Horizontally Interpolate Aerosol Data - Process 12.2.2

Input Data Flows

APD Column Aerosol
APD Stratospheric Aerosol
PCP12

Output Data Flows

Horizontally Interpolated Aerosol Data

Process Specification

According to Reference 1, this horizontal interpolation will be a simple bilinear fit in longitude and latitude. Once complete, the aerosol data will be horizontally organized according to the CERES required 1.25-deg equal-area grid.

The CERES Science Team will indicate acceptable ranges for the external ancillary input data. These ranges will be stored on the PCP12 input file.

To horizontally interpolate both the stratospheric and column aerosol data, the following steps are required:

- If APD regional data are not within CERES Science Team acceptable ranges
  - Interpolate between nearest neighbor in space.
  - If this is not within acceptable ranges
    - Use approved climatological data.
  - End If
- End If
- Linearly interpolate in longitude.
- Linearly interpolate in latitude.

3.2.2.3 Temporally Interpolate Aerosol Data - Process 12.2.3

Input Data Flows

Horizontally Interpolated Aerosol Data
MOA Time

Output Data Flows

Column Aerosol Stats
MOA Column Aerosol
MOA Stratospheric Aerosol
Stratospheric Aerosol Stats

Process Specification

Temporal interpolation of APD total column aerosol and stratospheric aerosol data will be linear. This process will produce the hourly data required by CERES.

To temporally interpolate the APD data, the following is required for each region:

- If MOA time is different from APD sample time

  Linearly interpolate in time.

  End If

3.2.2.4 Update Aerosol QC Report Statistics - Process 12.2.4

Input Data Flows

Column Aerosol Stats
Stratospheric Aerosol Stats

Output Data Flows

Aerosol QC Stats

Process Specification:

This process will update the applicable QC report statistics for the current run of the Regrid Humidity and Temperature Subsystem. Since the required statistics related to processing are TBD, the necessary requirements to update them are also TBD.

3.2.3 Process GAP Data - Process 12.3

Input Data Flows

GAP
MOA Time
PCP12

Output Data Flows

Meteorological QC Stats
MOA Humidity Profile
MOA Surface Data
MOA Temp Profile
MOA Time

Process Specification:

From data contained on the GAP, surface temperature and pressure, along with profiles of geopotential height, temperature, and humidity that are a function of pressure, will be written to the MOA. The Regrid Humidity and Temperature Fields Subsystem will generate these profiles for the atmospheric levels specified by the PCP12 input file. The surface data and the remaining profile data will be interpolated by the techniques described in this section.

After ingestion, GAP surface and profile data will be horizontally and temporally interpolated. Next, the profile data will be vertically interpolated. These results will be written to the MOA output file. Statistics for the QC12 report that pertain to the meteorological data will also be accumulated during this process. These subprocesses are depicted in Figure 3-3, and are discussed in Sections 3.2.3.1, 3.2.3.2, 3.2.3.3, 3.2.3.4, and 3.2.3.5.

3.2.3.1 Ingest GAP Data - Process 12.3.1

Input Data Flows

GAP
MOA Time
PCP12

Output Data Flows

GAP Surface Data
GAP Temp & Humidity Profiles
MOA Time

Process Specification

For background information on this process, see Section 3.2.2.1.

Ingestion of GAP data requires the following steps:

- Follow steps listed in Section 3.2.2.1 for both profile and surface data.

3.2.3.2 Horizontally Interpolate Meteorological Data - Process 12.3.2

Input Data Flows

GAP Surface Data
GAP Temp & Humidity Profiles
PCP12

Output Data Flows

Horizontally Interpolated GAP Data

Process Specification:

GAP surface data and GAP profile data will need to be horizontally interpolated to conform with the required 1.25-deg equal-area grid. For most parameters, a simple bilinear interpolation in latitude and longitude is sufficient. However, according to Reference 1, the horizontal interpolation of humidity must be done in terms of specific humidity to avoid errors. There is some uncertainty regarding this requirement. Most likely, the humidity data contained on the GAP will be in terms of relative humidity. If use of specific humidity for the horizontal

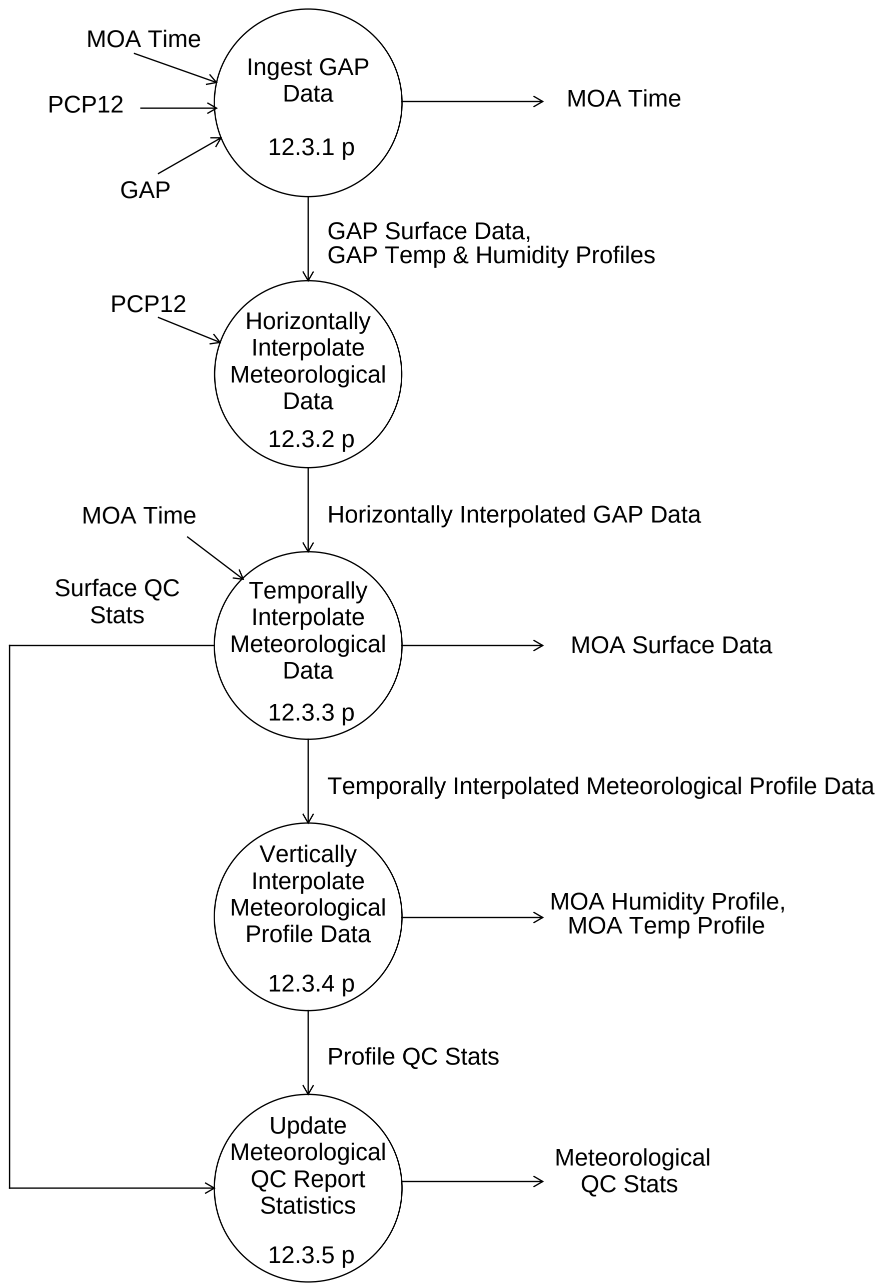

Figure 3-3. Data Flow Diagram for Process GAP Data

interpolation is required, the relative humidity will be converted to specific humidity before the horizontal interpolation and back to relative humidity after this interpolation. Along with investigating the actual requirements, members of Clouds and SARB Working Groups are currently working on the methods for back and forth conversions between relative and specific humidity. This Subsystem will implement the results of these investigations.

The CERES Science Team will indicate acceptable ranges for the external ancillary input data. These ranges will be stored on the PCP12 input file.

To horizontally interpolate the GAP data for each MOA region, the following steps are required:

- If GAP regional data is not within CERES Science Team acceptable ranges
  - Interpolate between nearest neighbor in space.
  - If this is not acceptable
    - Use approved climatological data.
  - End If

  End If
- Bilinearly interpolate temperature, pressure and geopotential height profiles.
- Bilinearly interpolate surface temperature and pressure.
- Interpolate humidity using CERES Science Team supplied algorithm.

3.2.3.3 Temporally Interpolate Meteorological Data - Process 12.3.3

Input Data Flows

Horizontally Interpolated GAP Data
MOA Time

Output Data Flows

MOA Surface Data
Surface QC Stats
Temporally Interpolated Meteorological Profile Data

Process Specification:

Temporal interpolation of GAP surface and profile data will be linear. This process will produce the hourly data required by CERES.

To temporally interpolate the GAP data, the following is required:

- If MOA time is different from GAP sampled time
  - Linearly interpolate in time for each 1.25-deg region.

  End If

3.2.3.4 Vertically Interpolate Meteorological Profile Data - Process 12.3.4

Input Data Flows

Temporally Interpolated Meteorological Profile Data

Output Data Flows

MOA Humidity Profile
MOA Temp Profile
Profile QC Stats

Process Specification:

To conform with CERES requirements, the GAP profiles for temperature, humidity, and geopotential height need to be vertically interpolated as a function of pressure.

To vertically interpolate the GAP data, the following steps are required:

- According to Reference 1, for temperature, apply the following equation

$$T_x = T_1 + ((T_1 - T_2) / \ln(P_1 / P_2)) * \ln(P_x / P_1),$$

where T_x is the temperature at the desired pressure level, P_x, which lies between P_1 and P_2 ($P_1 > P_2$).

- Linearly interpolate relative humidity using algorithm to be supplied by the CERES Science Team.
- Linearly interpolate geopotential height.

3.2.3.5 Update Meteorological QC Report Statistics - Process 12.3.5

Input Data Flows

Profile QC Stats
Surface QC Stats

Output Data Flows

Meteorological QC Stats

Process Specification:

See discussion in Section 3.2.2.4 regarding updating quality control report statistics.

3.2.4 Process MWH Data - Process 12.4

Input Data Flows

MOA Humidity Profile
MOA Time
MWH
PCP12

Output Data Flows

MOA Column Precip Water
MW Humidity QC Stats

Process Specification:

MWH data consists of column precipitable water, which, after ingestion, will be interpolated horizontally and then temporally. Statistics for the QC12 report that pertain to the column precipitable water data will also be accumulated during this process. These subprocesses are depicted in Figure 3-4, and are discussed in Sections 3.2.4.1, 3.2.4.2, 3.2.4.3, and 3.2.4.4.

If column precipitable water is not available from an approved microwave instrument, then the column precipitable water derived from the previously calculated humidity profile will be written to the MOA.

3.2.4.1 Ingest MWH Data - Process 12.4.1

Input Data Flows

MOA Time
MWH
PCP12

Output Data Flows

MWH Column Precip Water

Process Specification:

For background information on this process, see Section 3.2.2.1.

Ingestion of MWH data requires the following steps:

- Follow steps listed in Section 3.2.2.1.

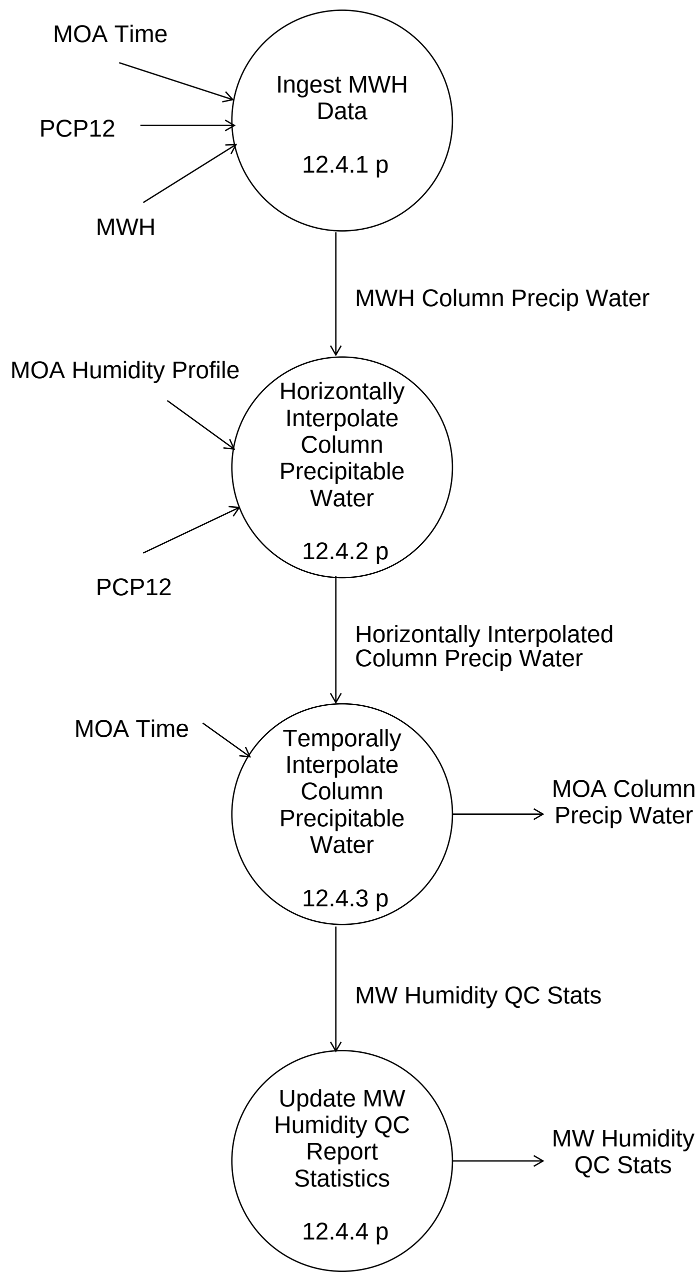

Figure 3-4. Data Flow Diagram for Process MWH Data

3.2.4.2 Horizontally Interpolate Column Precipitable Water - Process 12.4.2

Input Data Flows

MOA Humidity Profile
MWH Column Precip Water
PCP12

Output Data Flows

Horizontally Interpolated Column Precip Water

Process Specification:

According to Reference 1, the horizontal interpolation will be simple bilinear in longitude and latitude. Once complete, the column precipitable water will be horizontally organized according to the CERES required 1.25-deg equal-area grid. Unlike the profiled humidity data, conversion to specific humidity terms is not necessary for the column precipitable water.

If MWH data is not available or are not within acceptable ranges, then the column water vapor burden can be calculated from the humidity profile that originated with GAP data. This technique will be provided by the CERES Science Team. The CERES Science Team will indicate acceptable ranges for the external ancillary input data. These ranges will be stored on the PCP12 input file.

To horizontally interpolate the microwave humidity data, the following steps are required for each 1.25-deg region:

- If MWH data is available and within CERES Science Team acceptable ranges
  - Linearly interpolate in longitude.
  - Linearly interpolate in latitude.

  Else
  - Calculate column loaded humidity data from previously calculated humidity profile data.

  End If

3.2.4.3 Temporally Interpolate Column Precipitable Water - Process 12.4.3

Input Data Flows

Horizontally Interpolated Column Precip Water
MOA Time

Output Data Flows

MOA Column Precip Water
MW Humidity QC Stats

Process Specification:

Temporal interpolation of MWH data will be linear. This process will produce the hourly data required by CERES. If MWH data is not available, no temporal interpolation is required since the humidity profile is already temporally interpolated.

To temporally interpolate the MWH data, the following is required:

- If MWH data is available and the MOA time is different from MWH sampled time
    - Linearly interpolate in time for each 1.25-deg region

  End If

3.2.4.4 Update MW Humidity QC Report Statistics - Process 12.4.4

Input Data Flows

MW Humidity QC Stats

Output Data Flows

MW Humidity QC Stats

Process Specification:

See discussion in Section 3.2.2.4 regarding updating quality control report statistics.

3.2.5 Process OPD Data - Process 12.5

Input Data Flows

MOA Time
OPD
PCP12

Output Data Flows

MOA Column Ozone
MOA Ozone Profile Data
Ozone QC Stats

Process Specification:

OPD data consists of stratospheric ozone along with total column ozone. After ingestion, both the OPD stratospheric and column data will be horizontally and temporally interpolated, and then a vertical profile of the ozone data will be calculated from the stratospheric ozone data. These results will later be written to the MOA output file. Statistics for the QC12 report that pertain to the ozone data will also be accumulated during this process. These subprocesses are depicted in Figure 3-5, and are discussed in Sections 3.2.5.1, 3.2.5.2, 3.2.5.3, 3.2.5.4, and 3.2.5.5.

3.2.5.1 Ingest OPD Data - Process 12.5.1

Input Data Flows

MOA Time
OPD
PCP12

Output Data Flows

OPD Column Ozone
OPD Stratospheric Ozone
Stratospheric Ozone Source Flag

Process Specification:

For background information on this process, see Section 3.2.2.1.

Ingestion of OPD data requires the following steps:

- Follow steps listed in Section 3.2.2.1 for both column ozone and stratospheric ozone.

3.2.5.2 Horizontally Interpolate OPD Data - Process 12.5.2

Input Data Flows

OPD Column Ozone
OPD Stratospheric Ozone
PCP12

Output Data Flows

Horizontally Interpolated OPD Data

Process Specification

According to Reference 1, the horizontal interpolation will be simple bilinear in longitude and latitude. Once complete, the ozone data will be horizontally organized according to the CERES required 1.25-deg equal-area grid.

The CERES Science Team will indicate acceptable ranges for the external ancillary input data. These ranges will be stored on the PCP12 input file.

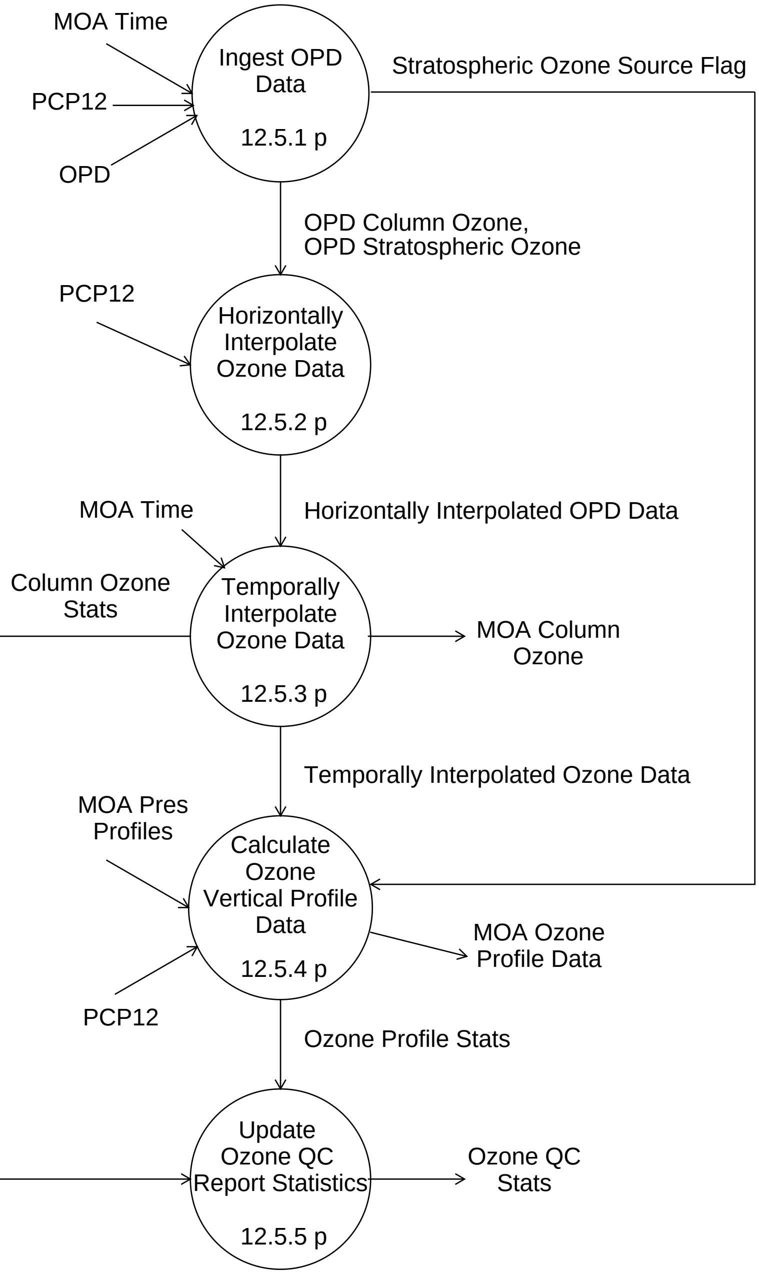

Figure 3-5. Data Flow Diagram for Process OPD Data

To horizontally interpolate both the stratospheric and column ozone data, the following steps are required for each 1.25-deg region:

- If OPD regional data are not within CERES Science Team acceptable ranges
  Interpolate between nearest neighbor in space.
  If this is not acceptable
  Use approved climatological data.
  End If
  End If
- Linearly interpolate in longitude.
- Linearly interpolate in latitude.

3.2.5.3 Temporally Interpolate OPD Data - Process 12.5.3

Input Data Flows
Horizontally Interpolated OPD Data
MOA Time

Output Data Flows
Column Ozone Stats
MOA Column Ozone
Temporally Interpolated Ozone Data

Process Specification:

Temporal interpolation of OPD column ozone and stratospheric ozone data will be linear. This process will produce the hourly data required by CERES.

To temporally interpolate the OPD data, the following is required:

- If MOA time is different from OPD sampled time
  Linearly interpolate in time for each 1.25-deg region.
  End If

3.2.5.4 Calculate Ozone Vertical Profile Data - Process 12.5.4

Input Data Flows
MOA Pres Profile
PCP12
Stratospheric Ozone Source Flag
Temporally Interpolated Ozone Data

Output Data Flows

MOA Ozone Profile Data
Ozone Profile Stats

Process Specification:

Reference 1 states that the vertical distribution of ozone will be in accordance with the approved climatological profiles. This process will determine the ozone content for specific atmospheric levels by applying level-specific weights to the stratospheric ozone data. Since some sources of stratospheric ozone data may provide some vertical profiling, these level-specific weights will also be source-specific. The atmospheric levels to be included in this vertical profile, along with the level-specific weights, will be included in the PCP12 file.

To calculate the vertical ozone profile data, the following is required for each 1.25-deg region:

- Determine source of stratospheric ozone data
- For each atmospheric level included in the ozone profile
  Apply level-specific, source-specific weight to stratospheric ozone data.

3.2.5.5 Update Ozone QC Report Statistics - Process 12.5.5

Input Data Flows

Column Ozone Stats
Ozone Profile Stats

Output Data Flows

Ozone QC Stats

Process Specification:

See discussion in Section 3.2.2.4 regarding updating quality control report statistics.

3.2.6 Finalizing Processing - Process 12.6

Input Data Flows

Aerosol QC Stats
Meteorological QC Stats
MOA Column Aerosol
MOA Column Ozone
MOA Column Precipitable Water
MOA Humidity Profile
MOA Metadata
MOA Time

MOA Ozone Profile Data
MOA Stratospheric Aerosol
MOA Surface Data
MOA Temp Profile
MW Humidity QC Stats
Ozone QC Stats

Output Data Flows

META12
MOA
QC12

Process Specification:

After all of the input data have been ingested and processed, the QC report, QC12, and the metadata file, META12, need to be generated. The MOA data calculated throughout the current run will also need to be stored on the MOA file, and META12 needs to be stored as a permanent file. These subprocesses are depicted in Figure 3-6, and discussed in Sections 3.2.6.1 and 3.2.6.2.

3.2.6.1 QC Report Generation - Process 12.6.1

Input Data Flows

Aerosol QC Stats
Meteorological QC Stats
MOA Metadata
MOA Time
MW Humidity QC Stats
Ozone QC Stats

Output Data Flows

MOA Metadata
MOA Time
QC12

Process Specification:

Since the contents of QC12 are TBD, the requirements to generate it are TBD. The QC12 may contain some of the same metadata required to be included in the META12 file.

The following actions are required:

- Finalize MOA metadata.
- Calculate final statistics.
- Generate QC12.

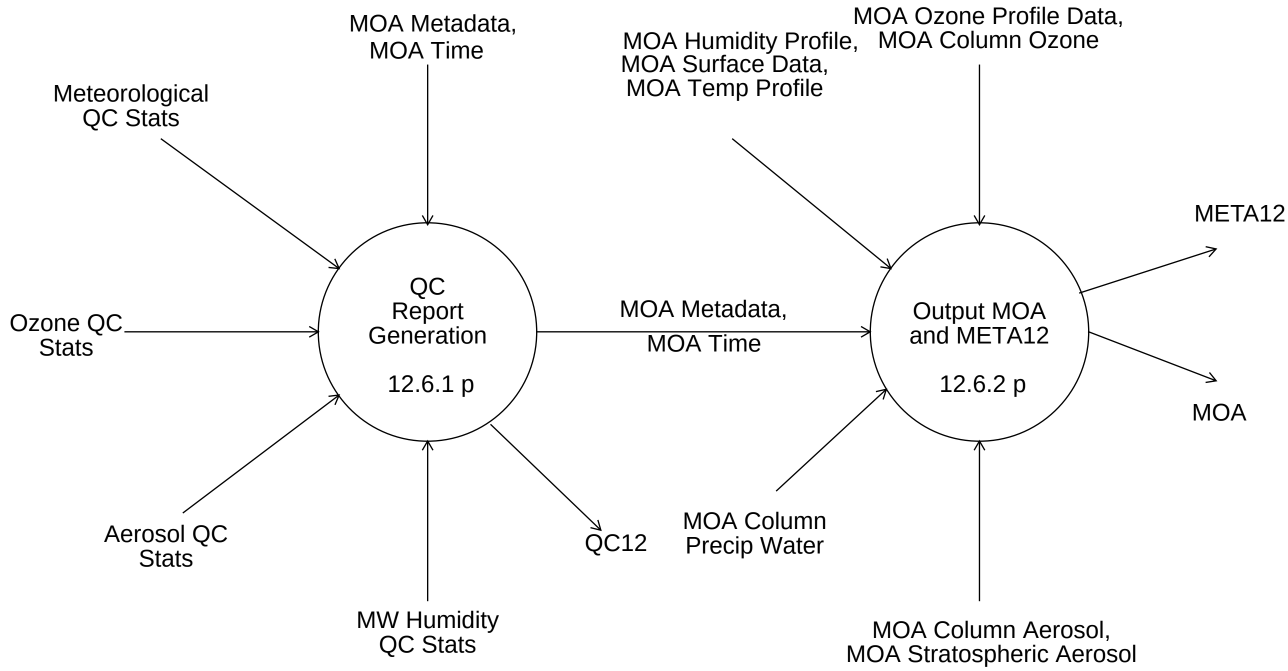

Figure 3-6. Data Flow Diagram for Finalizing Processing

3.2.6.2 Output MOA and META12 - Process 12.6.2

Input Data Flows

MOA Column Aerosol
MOA Column Ozone
MOA Column Precip Water
MOA Humidity Profile
MOA Metadata
MOA Ozone Profile Data
MOA Stratospheric Aerosol
MOA Surface Data
MOA Temp Profile
MOA Time

Output Data Flows

META12
MOA

Process Specification:

To finalize processing of the Regrid Humidity and Temperature Fields Subsystem, the hourly MOA file and associated metadata file, META12, need to be written to permanent storage. This process will comply with any EOSDIS requirements that may exist.

The following steps are required to finalize processing of this Subsystem:

- Generate MOA file.
- Generate META12.

3.3 Design Goals and Constraints

There are three major concerns that the designer of the Regrid Humidity and Temperature Fields Subsystem will need to keep in mind. These concerns include the following:

1. The sources of the external ancillary input data (APD, GAP, MWH, and OPD) are not certain; therefore, temporal and spatial resolution of the input data are not certain. Also, if an external source is either not available or not acceptable, then a climatology approved by the CERES Science Team will be used.

2. The external ancillary input data must be accessed via the EOSDIS Toolkit.

3. There may be some existing code, particularly for the horizontal interpolation processes, developed by the Clouds and SARB Working Groups that can be used for some of these sections.

3.4 Resource Use

While the need for a specific compiler has not been specified, existing code will be delivered in the FORTRAN programming language. Any new development by the DMT is to be in FORTRAN.

CPU resource requirements cannot sufficiently be estimated at this time. There is no significant heritage code for this Subsystem, such as for other CERES subsystems that are based on existing ERBE subsystems. The uncertainty of the external ancillary input data sources, and hence, the uncertainty of the spatial and temporal resolutions of these data also makes estimates of required CPU resources uncertain.

References

1. Clouds and the Earth's Radiant Energy System (CERES) Algorithm Theoretical Basis Document, Subsystem 12.0, Gupta, S.K., Anne C. Wilber, N.A. Ritchey, Wayne L. Darnell, F.G. Rose, Thomas P. Charlock, Atmospheric Sciences Division, NASA Langley Research Center, Hampton, VA, April 1994.

2. PGS Toolkit Users Guide for the ECS Project (194-809-SD4-001), Version 1 Final, May 1994.

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

Abbreviations and Acronyms

APD	Aerosol Product
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High-Resolution Radiometer
CERES	Clouds and the Earth’s Radiant Energy System
DMT	Data Management Team
ECMWF	European Centre for Medium Range Weather Forecasting
ECS	EOSDIS Core System
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
GAP	Gridded Analysis Product
hPa	Hectopascal
META12	Metadata for Subsystem 12
MISR	Multi-Angle Imaging Spectro-Radiometer
MOA	Meteorological, Ozone, and Aerosol Product
MODIS	Moderate Resolution Imaging Spectrometer
MWH	Microwave Humidity
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
OPD	Ozone Profile and Column Product
PCP12	Processing and Control Parameters for Subsystem 12
PGE	Product Generation Executable
PGS	Product Generation System
QC	Quality Control
QC12	Quality Control Report for Subsystem 12
SAGE	Stratospheric Aerosol and Gas Experiment
SARB	Surface and Atmospheric Radiation Budget
SBUV	Solar Backscatter Ultraviolet Radiometer
SSM/I	Special Sensor Microwave/Imager

TBD	To Be Determined
TMI	TRMM Microwave Imager
TISA	Time Interpolation and Spatial Averaging
TOMS	Total Ozone Mapping Spectrometer
TRMM	Tropical Rainfall Measuring Mission