Joint Center for Satellite Data Assimilation

CRTM: v1.2 User Guide

January, 2009

Change History

Date	Author	Change
2009-01-30	P.van Delst	Initial release.
2009-02-03	P.van Delst	Updated chapter 2 with descriptions of the example code and coefficient tarballs. Added explanation of layering convention in chapter 4.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Conventions

The following are conventions that have been adhered to in the current release of the CRTM framework. They are guidelines intended to make understanding the code at a glance easier, to provide a recognisable "look and feel", and to minimise name space clashes.

1.1.1 Naming of Structure Types and Instances of Structures

The derived data type, or structure[1] type, naming convention adopted for use in the CRTM is,

`[CRTM_]`*name*`_type`

where *name* is an identifier that indicates for what a structure is to be used. All structure type names are suffixed with "`_type`" and CRTM-specific structure types are prefixed with "`CRTM_`". Some examples are,

```
SpcCoeff_type
CRTM_Atmosphere_type
CRTM_RTSolution_type
```

An instance of a structure is then referred to via its *name*, or some sort of derivate of its *name*. Some structure declarations examples are,

```
TYPE(SpcCoeff_type)         :: SpcCoeff
TYPE(CRTM_Atmosphere_type)  :: atm, atm_K
TYPE(CRTM_RTSolution_type)  :: rts, rts_K
```

where the K-matrix structure variables are identified with a "`_K`" suffix. Similarly, tangent-linear and adjoint variables are suffixed with "`_TL`" or "`_AD`" respectively.

1.1.2 Naming of Definition Modules

Modules containing structure type definitions are termed *definition modules*. These modules contain the actual structure definitions as well as various utility procedures to allocate, destroy, copy etc. structures of the designated type. The naming convention adopted for definition modules in the CRTM is,

`[CRTM_]`*name*`_Define`

where, as with the structure type names, all definition module names are suffixed with "`_Define`" and CRTM-specific definition modules are prefixed with "`CRTM_`". Some examples are,

[1] The terms "derived type" and "structure" are used interchangably in this document.

```
SpcCoeff_Define
CRTM_Atmosphere_Define
CRTM_RTSolution_Define
```

The actual source code files for these modules have the same name with a "`.f90`" suffix.

1.1.3 Naming of Application Modules

Modules containing the routines that perform the calculations for the various components of the CRTM are termed *application modules*. The naming convention adopted for application modules in the CRTM is,

`CRTM_`*name*

Some examples are,

```
CRTM_AtmAbsorption
CRTM_SfcOptics
CRTM_RTSolution
```

However, in this case, *name* does not necessarilty refer just to a structure type. Separate application modules are used as required to split up tasks in manageable (and easily maintained) chunks. For example, separate modules have been provided to contain the cloud and aerosol optical property retrieval; similarly separate modules handle different surface types for different instrument types in computing surface optics.

Again, the actual source code files for these modules have the same name with a "`.f90`" suffix. Note that not all definition modules have a corresponding application module since some structures (e.g. SpcCoeff structures) are simply data containers.

1.1.4 Naming of I/O Modules

Modules containing routines that read and write data from and to files are, naturally, termed I/O modules. Not all data structures have associated I/O modules. The naming convention adopted for these modules in the CRTM is,

`[CRTM_]`*name*`_Binary_IO`

or

`[CRTM_]`*name*`_netCDF_IO`

Some examples are,

```
SpcCoeff_Binary_IO
SpcCoeff_netCDF_IO
CRTM_Atmosphere_Binary_IO
CRTM_RTSolution_Binary_IO
```

As with the other module types, the actual source code files for these modules have the same name with a "`.f90`" suffix.

In the context of the CRTM, the term "Binary" is a euphemisn for sequential, unformatted I/O in Fortran. Additionally, since some data structure constructions are not naturally amenable to fixed length data records (at least, not without significant wastage of space), not all data structures used in the CRTM have both netCDF and Binary I/O modules.

1.2 Components

The CRTM is designed around three broad categories: atmospheric optics, surface optics and radiative transfer.

1.2.1 Atmospheric Optics

(`AtmOptics`) This category includes computation of the absorption by atmospheric gases (`AtmAbsorption`) and scattering and absorption by both clouds (`CloudScatter`) and aerosols (`AerosolScatter`).

The gaseous absorption component computes the optical depth of the absorbing constituents in the atmosphere given the pressure, temperature, water vapour, and ozone concentration[2] profiles.

The scattering component simply interpolates look-up-tables (LUTs) of optical properties – such as mass extinction coefficient and single scatter albedo – for cloud and aerosol types that are then used in the radiative transfer component. See tables A.4 and A.5 for the valid cloud and aerosol types, respectively, that are valid in the CRTM.

1.2.2 Surface Optics

(`SfcOptics`) This category includes the computation of surface emissivity and reflectivity for four gross surface types (land, water, snow, and ice). Each gross surface type has a specified number of specific surface types associated with it. See tables A.8, A.9, A.10, and A.11 for the land, water, snow, and ice surface types, respectively, that are valid in the CRTM.

The CRTM utilises separate models for each gross surface type for each spectral type (infrared and microwave). These models can be either physical models or database/LUT type of models.

1.2.3 Radiative Transfer Solution

(`RTSolution`) This category takes the `AtmOptics` and `SfcOptics` data and solves the radiative transfer problem either clear or scattering atmospheres.

1.3 Models

The CRTM is composed of four models: a forward model, a tangent-linear model, an adjoint model, and a K-matrix model. These can be represented as shown in equations 1.1a to 1.1d.

$$\mathbf{T_B}, \mathbf{R} = \mathbf{F}(\mathbf{T}, \mathbf{q}, T_s, ...) \tag{1.1a}$$

$$\delta\mathbf{T_B}, \delta\mathbf{R} = \mathbf{H}(\mathbf{T}, \mathbf{q}, T_s, ...\delta\mathbf{T}, \delta\mathbf{q}, \delta T_s, ...) \tag{1.1b}$$

$$\delta^*\mathbf{T}, \delta^*\mathbf{q}, \delta^* T_s, ... = \mathbf{H^T}(\mathbf{T}, \mathbf{q}, T_s, ...\delta^*\mathbf{T_B}) \tag{1.1c}$$

$$\delta^*\mathbf{T}_l, \delta^*\mathbf{q}_l, \delta^* T_{s,l}, ... = \mathbf{K}(\mathbf{T}, \mathbf{q}, T_s, ...\delta^*\mathbf{T_B}) \text{ for } l = 1, 2, ..., L \tag{1.1d}$$

Here $\mathbf{F}$ is the forward operator that, given the atmospheric temperature and absorber profiles ($\mathbf{T}$ and $\mathbf{q}$), surface temperature (T_s), etc., produces a vector of channel brightness temperatures ($\mathbf{T_B}$) and radiances ($\mathbf{R}$).

The tangent-linear operator, $\mathbf{H}$, represents a linearisation of the forward model about $\mathbf{T}$, $\mathbf{q}$, T_s, etc. and when also supplied with perturbations about the linearisation point (quantities represented by the δ's) produces the expected perturbations to the brightness temperature and channel radiances.

The adjoint operator, $\mathbf{H^T}$, is simply the transpose of the tangent-linear operator and produces gradients (the quantities represented by the δ^*'s). It is worth noting that, in the CRTM, these adjoint gradients are accumulated over channel and thus do not represent channel-specific Jacobians.

[2] Additional trace gas absorption capabilities are being added.

The K-matrix operator[3], **K**, is effectively the same as the adjoint but with the results preserved by channel (indicated via the subscript l). In the CRTM, the adjoint and K-matrix results are related by,

$$\delta^* x = \sum_{l=1}^{L} \delta^* x_l \tag{1.2}$$

Thus, the K-matrix results are the derivatives of the diagnostic variables with respect to the prognostic variables, e.g.

$$\delta^* x_l = \frac{\partial T_{B,l}}{\partial x} \tag{1.3}$$

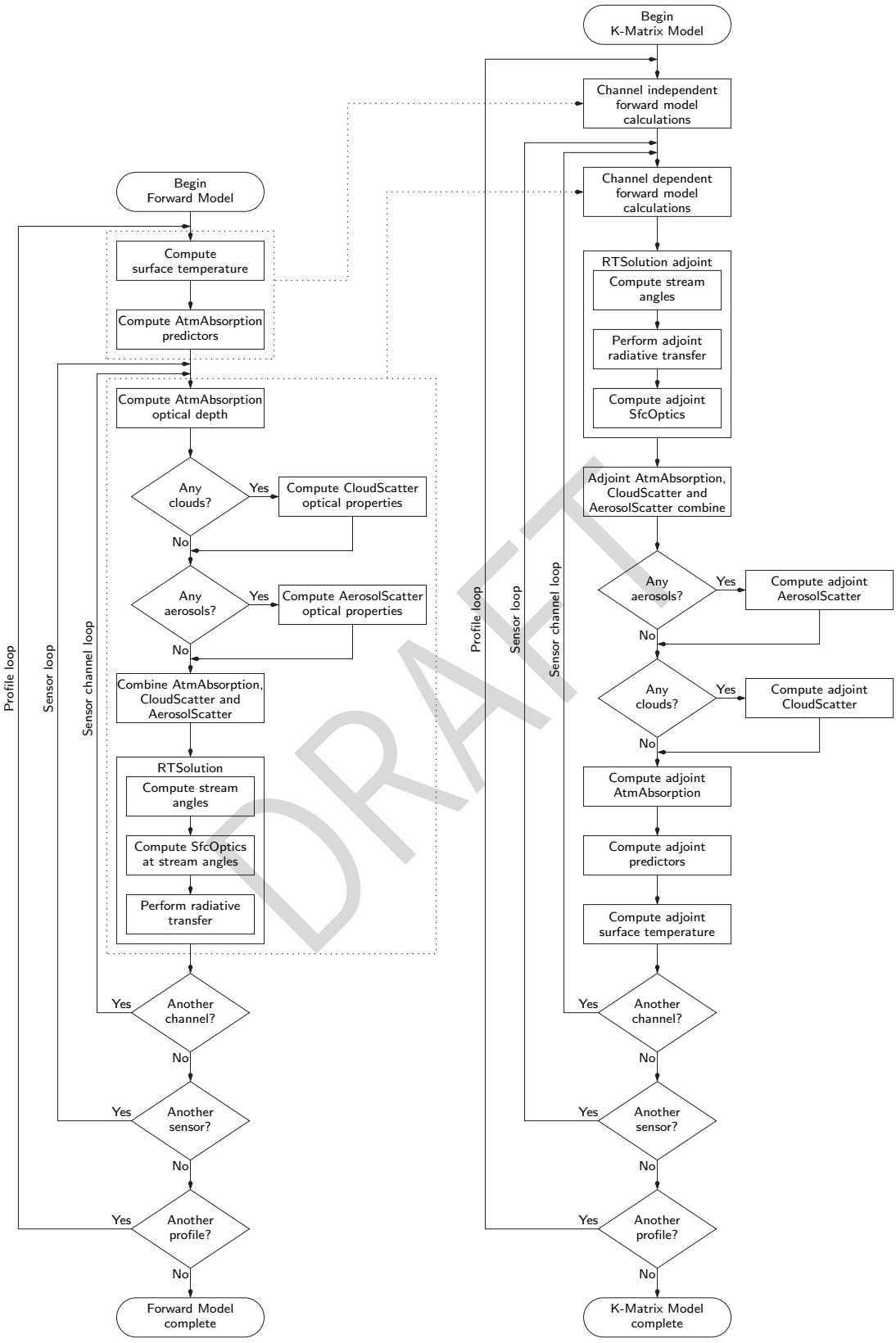
Typically, only the forward or K-matrix models are used in applications. However, the intermediate models are generated and retained for maintenance and testing purposes. Any changes to the CRTM forward model are translated to the tangent-linear model and the latter tested against the former. When the tangent-linear model changes have been verified, the changes then translated to the adjoint model and, as before, the latter is tested against the former. This process is repeated for the adjoint-to-K-matrix models also.

1.4 Design Framework

This document is not really the place to fully discuss the design framework of the CRTM, so it will only be briefly mentioned here. Where appropriate, different physical processes are isolated into their own modules. The CRTM interfaces presented to the user are, at their core, simply drivers for the individual parts. This is shown schematically in the forward and K-matrix model flowcharts of figure 1.1.

A fundamental tenet of the CRTM design is that each component define its own structure definition and application modules to facilitate independent development of an algorithm outside of the mainline CRTM development. By isolating different processes, we can more easily identify requirements for an algorithm with a view to minimise or eliminate potential software conflicts and/or redundancies. The end result sought via this approach is that components developed by different groups can more easily be added into the framework leading to faster implementation of new science and algorithms.

[3]The term K-matrix is used because references to this operation in the literature commonly use the symbol **K**



(a) Forward Model (b) K-Matrix Model

Figure 1.1: Flowchart of the CRTM Forward and K-Matrix models.

2 How to obtain the CRTM

2.1 CRTM ftp download site

The CRTM source code and coefficients, and example programs, are released as compressed tarballs[1] via the CRTM ftp site:

`ftp://ftp.emc.ncep.noaa.gov/jcsda/CRTM/`

A snapshot of that site is shown in figure 2.1. Note that the source code and coefficients can be released separately as updates to either one can occur independently of the other. Also note that additional releases, e.g. beta or experimental branches, are also made available on this ftp site.

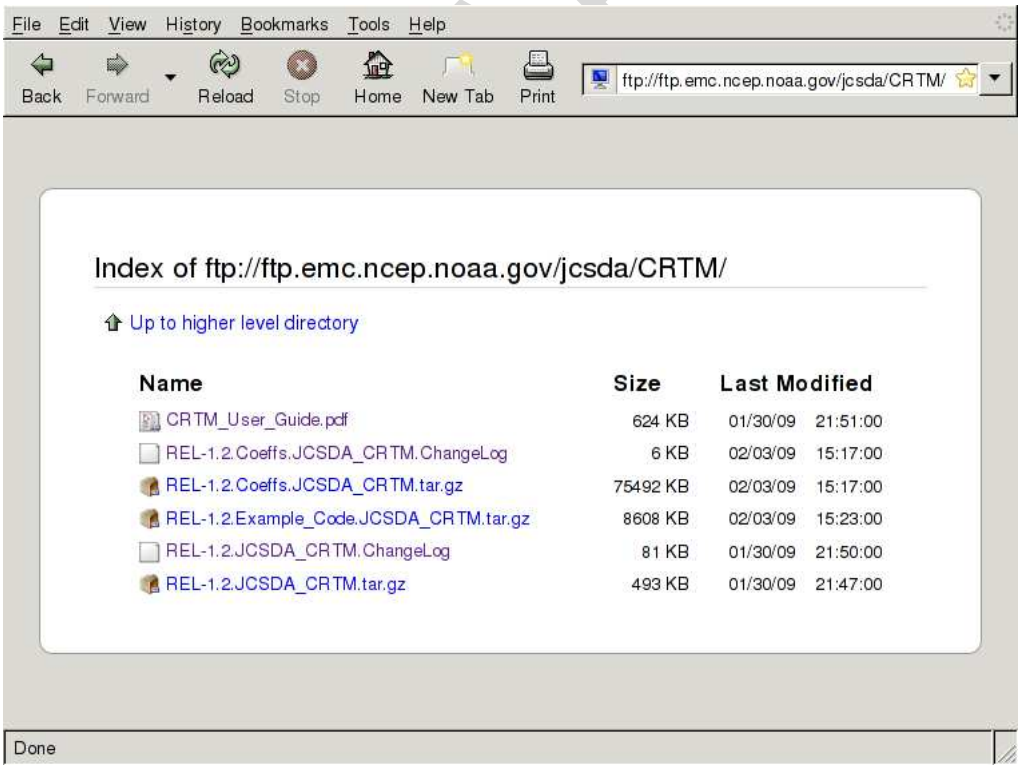


Figure 2.1: The CRTM ftp site contents (as on Feb.03, 2009)

[1] A compressed (e.g. gzip'd) tape archive (tar) file.

2.2 Coefficient Data

The tarball labeled as "`Coeffs`" packages up all the transmittance, spectral, cloud, aerosol, and emissivity coefficient data needed by the CRTM. The Coeffs tarball directory structure is organised by coefficient and format type as shown below,

```
CRTM_Coefficients/
 |- SpcCoeff/
 |    |- Big_Endian/
 |    |- Little_Endian/
 |    `- netCDF/
 |- TauCoeff/
 |    |- Big_Endian/
 |    |- Little_Endian/
 |    `- netCDF/
 |- AerosolCoeff/
 |    |- Big_Endian/
 |    |- Little_Endian/
 |    `- netCDF/
 |- CloudCoeff/
 |    |- Big_Endian/
 |    |- Little_Endian/
 |    `- netCDF/
 `- EmisCoeff/
      |- Big_Endian/
      |- Little_Endian/
      `- netCDF/
```


Both big- and little-endian format files are provided to save users the trouble of switching what they use for their system. Planned future updates to the CRTM include changing the CRTM initialisation I/O functions to the netCDF versions so, eventually, only the netCDF datafiles will be provided.

To run the CRTM, all the required coefficient files need to be in the same path (see the CRTM initialisation function description) so users will have to move the datafiles as required.

2.3 Example Programs

The tarball labeled as "`Example_Code`" contains two completely independent example programs – one showing how to call the CRTM Forward model and the other for the K-matrix model. The Example Code tarball directory structure looks like that below, with the example programs higlighted in blue,

```
Example_Code/
 |- Coefficient_Data/
 |    |- AerosolCoeff.bin
 |    |- CloudCoeff.bin
 |    |- EmisCoeff.bin
 |    |- amsua_n18.SpcCoeff.bin
 |    |- amsua_n18.TauCoeff.bin
 |    |- hirs4_n18.SpcCoeff.bin
 |    |- hirs4_n18.TauCoeff.bin
 |    |- mhs_n18.SpcCoeff.bin
 |    `- mhs_n18.TauCoeff.bin
```

```
|- Forward/
|   |- Example_Forward.f90
|   |- Makefile
|   |- README.FIRST
|   |- run_Example_Forward.sh*
|   `- Results/
|       |- amsua_n18.Forward.output
|       |- hirs4_n18.Forward.output
|       `- mhs_n18.Forward.output
`- K_Matrix/
    |- Example_K_Matrix.f90
    |- Makefile
    |- README.FIRST
    |- run_Example_K_Matrix.sh*
    `- Results/
        |- amsua_n18.K_Matrix.output
        |- hirs4_n18.K_Matrix.output
        `- mhs_n18.K_Matrix.output
```

The example programs are written to search for the test coefficient files' (all big-endian) relative location as shown. There are two additional things to note about the example program makefiles,

- they assume the CRTM library has already been built (see chapter 3 for how to do that) *and* is in the generic location, `$(HOME)/local/CRTM`,
- `gfortran` is the default compiler.

You should modify the example code makefiles for your own system. Other compiler switches are provided in the makefile for guidance.

The shell script files, `run_Example_Forward.sh` and `run_Example_K_Matrix.sh`, run the example programs as well as compare their output to that supplied in the `Results` directory.

3 How to build the CRTM library

3.1 Build Files

The build system for the CRTM is currently quite unsophisticated. It consists of a number of make and include files in the CRTM tarball hierarchy:

`makefile` : The main makefile
`make.macros` : The include file containing all the defined macros, including the compiler and linker flags.
`make.rules` : The include file containing the suffix rules for compiling Fortran95 source code.

3.2 Predefined Build Targets

Several targets are available for specific compilers. The compilers and makefile target names are shown in table 3.1. Both "production" and debug target names are supplied, with the former using compiler switches to produce fast code and the latter using compiler switches to turn on all the available debugging capabilities. Note that the debug targets will produce executables much slower than the production builds.

Platform	Compiler	Production Target	Debug Target
Linux	GNU gfortran	`gfortran`	`gfortran_debug`
	Lahey lf95	`lahey`	`lahey_debug`
	Intel ifort	`intel`	`intel_debug`
	PGI pgf95	`pgi`	`pgi_debug`
	g95	`g95`	`g95_debug`
	Absoft†	`absoft`	`absoft_debug`
IBM	AIX xlf95	`ibm`	`ibm_debug`
HP	HP-UX f90†	`hp`	`hp_debug`
SGI	IRIX f90†	`sgi`	`sgi_debug`
Sun	Solaris f90†	`sun`	`sun_debug`

Table 3.1: Predefined makefile targets for CRTM library build. († Untested.)

The actual compiler and switch definitions are listed in the `make.macros` file. Also note that not all of the above compilers have been tested for the current release.

3.3 Building the library

The default build is performed by simply typing,

```
make
```

and is operating system sensitive in that the compiler is selected based on the platform. For example, if you build on an IBM/AIX system, the xlf95 compiler is invoked. Doing the same on a linux or MacOSX system invokes the default linux compiler; currently this is the GNU gfortran f95 compiler.

So, if you are using a linux or MacOSX system and want to modify the *default* CRTM build (different compiler, different switches), you will need to edit the `make.macros` file. At the bottom of this file, you will see the following macro definitions,

```
LINUX_FLAGS = $(LINUX_FLAGS_GFORTRAN)
#LINUX_FLAGS = $(LINUX_FLAGS_LAHEY)
#LINUX_FLAGS = $(LINUX_FLAGS_PGI)
#LINUX_FLAGS = $(LINUX_FLAGS_INTEL)
#LINUX_FLAGS = $(LINUX_FLAGS_G95)
```

where you can see the generic `LINUX_FLAGS` macros is set to `LINUX_FLAGS_GFORTRAN`. To use any of the other defined compilers (Lahey, PGI, Intel, or g95), simply uncomment the required line. For example, if your compiler of choice is Intel `ifort` and you want that to be the default build, the change would simply be

```
#LINUX_FLAGS = $(LINUX_FLAGS_GFORTRAN)
#LINUX_FLAGS = $(LINUX_FLAGS_LAHEY)
#LINUX_FLAGS = $(LINUX_FLAGS_PGI)
LINUX_FLAGS = $(LINUX_FLAGS_INTEL)
#LINUX_FLAGS = $(LINUX_FLAGS_G95)
```

Note, however, than an Intel `ifort` build can also be obtained by using the predefined makefile targets as shown in table 3.1.

3.4 Installing the library

An very simple install target is specified in the supplied makefile to put all the necessary include files (the generated `*.mod` files containing all the procedure interface information) in an `/include` subdirectory and the library itself (the generated `libCRTM.a` file) in a `/lib` subdirectory. The make command is

```
make install
```

The `/include` and `/lib` subdirectories can then be moved to a more suitable location on your system, for example: `$HOME/local/CRTM`

3.5 Linking to the library

Let's assume you've built the CRTM library and placed the `/include` and `/lib` subdirectories in your own local area, `$HOME/local/CRTM`. In the makefile for your application that uses the CRTM, you will need to add

```
-I$HOME/local/CRTM/include
```

to your list of compilation switches, and the following to your list of link switches,

```
-L$HOME/local/CRTM/lib -lCRTM
```

4 How to use the CRTM library

4.1 Step by Step Guide

This section will hopefully get you started using the CRTM library as quickly as possible. Refer to the following sections for more information about the structures and interfaces.

The examples shown here assume you are processing one sensor at a time. The CRTM can handle multiple sensors at once, but specifying the input information in a simple way is difficult; e.g. the `GeometryInfo` structure that is used to specify the sensor viewing geometry – even sensors on the same platform typically have different numbers of fields-of-view (FOVs) per scan. For multiple sensor processing, we'll assume they will be separately processed in parallel.

Because there are many variations in what information is known ahead of time (and by "ahead of time" we mean at compile-time of your code), let's approach this via examples for a fixed number of atmospheric profiles, and a known sensors. It is left as an exercise to the reader to tailor calls to the CRTM in their application code according to their particular needs.

With regards to sensor identification, the CRTM uses a character string – refered to as the `Sensor_Id` – to distinguish sensors and platforms. The lists of currently supported sensors, along with their associated `Sensor_Id`'s, are shown in appendix B.

4.1.1 Step 1: Access the CRTM module

All of the CRTM user procedures, parameters, and derived data type definitions are accessible via the container module `CRTM_Module`. Thus, one needs to put the following statement in any calling program, module or procedure,

```
USE CRTM_Module
```

Once you become familiar with the components of the CRTM you require, you can also specify an `ONLY` clause with the `USE` statement,

```
USE CRTM_Module[, ONLY: only-list]
```

where *only-list* is a list of the symbols you want to "import" from `CRTM_Module`. This latter form is the preferred style for self-documenting your code; e.g. when you give the code to someone else, they will be able to identify from which module various symbols in your code originate.

4.1.2 Step 2: Declare the CRTM structures

To compute satellite radiances you need to declare structures for the following information,

1. Atmospheric profile data such as pressure, temperature, absorber amounts, clouds, aerosols, etc. Handled using the `Atmosphere` structure.

2. Surface data such as type of surface, temperature, surface type specific parameters etc. Handled using the `Surface` structure.
3. Geometry information such as sensor scan angle, zenith angle, etc. Handled using the `GeometryInfo` structure.
4. Instrument information, particularly which instrument(s), or sensor(s)[1], you want to simulate. Handled using the `ChannelInfo` structure.
5. Results of the radiative transfer calculation. Handled using the `RTSolution` structure.
6. Optional inputs. Handled using the `Options` structure.

Let's assume you want to process, say, 50 profiles for the NOAA-18 AMSU-A sensor which has 15 channels. The forward model declarations would look something like,

```
! Processing parameters
INTEGER     , PARAMETER :: N_SENSORS  =  1
INTEGER     , PARAMETER :: N_CHANNELS = 15
INTEGER     , PARAMETER :: N_PROFILES = 50
CHARACTER(*), PARAMETER :: SID(N_SENSORS) = (/'amsua_n18'/)
TYPE(CRTM_ChannelInfo_type)  :: chInfo(N_SENSORS)
TYPE(CRTM_GeometryInfo_type) :: gInfo(N_PROFILES)
! Forward declarations
TYPE(CRTM_Atmosphere_type)   :: atm(N_PROFILES)
TYPE(CRTM_Surface_type)      :: sfc(N_PROFILES)
TYPE(CRTM_RTSolution_type)   :: rts(N_CHANNELS,N_PROFILES)
```

If you are also interested in calling the K-matrix model, you will also need the following declarations,

```
! K-Matrix declarations
TYPE(CRTM_Atmosphere_type)   :: atm_K(N_CHANNELS,N_PROFILES)
TYPE(CRTM_Surface_type)      :: sfc_K(N_CHANNELS,N_PROFILES)
TYPE(CRTM_RTSolution_type)   :: rts_K(N_CHANNELS,N_PROFILES)
```


4.1.3 Step 3: Initialise the CRTM

The CRTM is initialised by calling the `CRTM_Init()` function. This loads all the various coefficient data used by CRTM components into memory for later use. We'll assume that all the required datafiles reside in the subdirectory `./coeff_data` and follow on from the example of Step 2. The CRTM initialisation is profile independent, so we're only dealing with sensor information here. The CRTM initialisation function call looks like,

```
INTEGER :: errStatus
....
errStatus = CRTM_Init( chInfo, Sensor_Id=SID, File_Path='./coeff_data' )
IF ( errStatus /= SUCCESS ) THEN
  handle error...
END IF
```

Here we see for the first time how the CRTM functions let you know if they were successful. As you can see the `CRTM_Init()` function result is an error status that is checked against a parameterised integer error code, `SUCCESS`. The function result should *not* be tested against the actual value of the error code, just its parameterised name. Other available error code parameters are `FAILURE`, `WARNING`, and `INFORMATION` – although the latter is never used as a function result.

[1] The terms "instrument" and "sensor" are used interchangeably in this document.

4.1.4 Step 4: Allocate the CRTM structures

Now we need to allocate the *internal* components of the various CRTM structures where necessary to hold the input or output data. In this case, functions are used to perform these "internal" allocations. The function naming convention is `CRTM_Allocate_`*name* where, for typical usage, the CRTM structures that need to be allocated are the `Atmosphere`, `RTSolution` and, if used, `Options` structures. Potentially, the `SensorData` component of the `Surface` structure may also need to be allocated to allow for input of sensor observations for some of the NESDIS microwave surface emissivity models.

Allocation of the Atmosphere structures

First, we'll allocate the atmosphere structures to the required dimensions. The forward variable is allocated like so:

```
! Allocate the forward atmosphere structure
errStatus = CRTM_Allocate_Atmosphere( n_Layers   , &  ! Input
                                      N_ABSORBERS, &  ! Input (always 2)
                                      n_Clouds   , &  ! Input
                                      n_Aerosols , &  ! Input
                                      atm          )  ! Output
IF ( errStatus /= SUCCESS ) THEN
  handle error...
END IF
```

and the K-matrix variable is allocated by looping over all profiles,

```
! Allocate the K-matrix atmosphere structure
DO m = 1, N_PROFILES
  errStatus = CRTM_Allocate_Atmosphere( n_Layers   , &  ! Input
                                        N_ABSORBERS, &  ! Input (always 2)
                                        n_Clouds   , &  ! Input
                                        n_Aerosols , &  ! Input
                                        atm_k(:,m)   )  ! Output
  IF ( errStatus /= SUCCESS ) THEN
    handle error...
  END IF
END DO
```

Note that the number of absorbers is in all capitals. In the CRTM, this style convention indicates a parameter. A parameter is used for the number of absorbers in the current CRTM release because the number of absorbers is fixed at two: water vapour and ozone. Future CRTM releases will allow more flexibility in selecting the number of absorbers, but currently the number must be set to two.

4.1.5 Step 5: Fill the CRTM input structures with data

This step simply entails filling the input `atm`, `sfc` and `gInfo` structures with the required information. However, there are some issues that need to be mentioned:

- In the CRTM, all profile layering is from top-of-atmosphere (TOA) to surface (SFC). So, for an atmospheric profile layered as $k = 1, 2, ..., K$, layer 1 is the TOA layer and layer K is the SFC layer.
- In the `Atmosphere` structure, the `Climatology` component is not yet used.
- In the `Atmosphere` structure, *both* the level and layer pressure profiles must be specified.

- In the Atmosphere structure, the absorber profile data units *must* be mass mixing ratio for water vapour and ppmv for ozone. The Absorber_Units component is not yet utilised to allow conversion of different user-supplied concentration units.
- In the Surface structure, the sum of the coverage types *must* add up to 1.0.
- In the GeometryInfo structure, the sensor zenith and sensor scan angles should be consistent.
- Graphical definitions of the GeometryInfo structure sensor scan, sensor zenith, sensor azimuth, source zenith, and source azimuth angles are shown in figures A.8, A.9, A.10, A.11, and A.12 respectively.

For the K-matrix structures, you should zero the K-matrix *outputs*, atm_K, sfc_K,

```
! Zero the K-matrix OUTPUT structures
CALL CRTM_Zero_Atmosphere( atm_K )
CALL CRTM_Zero_Surface( sfc_K )
```

and initialise the K-matrix *input*, rts_K, to provide you with the derivatives you want. For example, if you want the atm_K, sfc_K outputs to contain brightness temperature derivatives, you should initialise rts_K like so,

```
! Initialise the K-Matrix INPUT to provide dTb/dx derivatives
rts_K%Radiance = ZERO
rts_K%Brightness_Temperature = ONE
```

Alternatively, if you want radiance derivatives returned in atm_K and sfc_K, the rts_K structure should be initialised like so,

```
! Initialise the K-Matrix INPUT to provide dR/dx derivatives
rts_K%Radiance = ONE
rts_K%Brightness_Temperature = ZERO
```

For computational efficiency, there is minimal input data checking done so the GIGO[2] principle applies.

4.1.6 Step 6: Call the required CRTM function

At this point, much of the prepatory heavy lifting has been done. The CRTM function calls themselves are quite simple. For the forward model we do,

```
Error_Status = CRTM_Forward( atm    , & ! Input
                             sfc    , & ! Input
                             gInfo  , & ! Input
                             chInfo , & ! Input
                             rts      ) ! Output
IF ( Error_Status /= SUCCESS ) THEN
  handle error...
END IF
```

and for the K-matrix model, the calling syntax is,

```
Error_Status = CRTM_K_Matrix( atm    , & ! Forward  input
                              sfc    , & ! Forward  input
                              rts_K  , & ! K-matrix input
                              gInfo  , & ! Input
```

[2] Garbage In, Garbage Out

```
                                chInfo, & ! Input
                                atm_K , & ! K-matrix output
                                sfc_K , & ! K-matrix output
                                rts     ) ! Forward  output
IF ( Error_Status /= SUCCESS ) THEN
  handle error...
END IF
```

Note that the K-matrix model also returns the forward model radiances. The tangent-linear and adjoint models have similar call structures and will not be shown here.

4.1.7 Step 7: Destroy the CRTM and cleanup

The last step is to cleanup. This involves calling the CRTM destruction function

```
Error_Status = CRTM_Destroy( chInfo )
IF ( Error_Status /= SUCCESS ) THEN
  handle error...
END IF
```

to deallocate all the shared coefficient data, as well as calling the individual structure destroy functions to deallocate as required. For the example here, that entails deallocating the forward and K-matrix `Atmosphere` structures, `atm` and `atm_K`,

```
Error_Status = CRTM_Destroy_Atmosphere(atm_K)
IF ( Error_Status /= SUCCESS ) THEN
  handle error...
END IF

Error_Status = CRTM_Destroy_Atmosphere(atm)
IF ( Error_Status /= SUCCESS ) THEN
  handle error...
END IF
```


4.2 Interface Descriptions

4.2.1 CRTM_Init interface

```
NAME:
      CRTM_Init

PURPOSE:
      Function to initialise the CRTM.

CALLING SEQUENCE:
      Error_Status = CRTM_Init( ChannelInfo                        , &
                                Sensor_ID        =Sensor_ID        , &
                                CloudCoeff_File  =CloudCoeff_File  , &
                                AerosolCoeff_File=AerosolCoeff_File, &
                                EmisCoeff_File   =EmisCoeff_File   , &
                                File_Path        =File_Path        , &
```

```
                          Quiet            =Quiet            , &
                          Process_ID       =Process_ID       , &
                          Output_Process_ID=Output_Process_ID, &
                          RCS_Id           =RCS_Id           , &
                          Message_Log      =Message_Log        )
```

OUTPUT ARGUMENTS:

ChannelInfo: ChannelInfo structure array populated based on the contents of the coefficient files and the user inputs.
UNITS: N/A
TYPE: CRTM_ChannelInfo_type
DIMENSION: Rank-1 (n_Sensors)
ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:

Sensor_ID: List of the sensor IDs (e.g. hirs3_n17, amsua_n18, ssmis_f16, etc) with which the CRTM is to be initialised. These Sensor ID are used to construct the sensor specific SpcCoeff and TauCoeff filenames containing the necessary coefficient data, i.e.
<Sensor_ID>.SpcCoeff.bin
and
<Sensor_ID>.TauCoeff.bin
for each sensor Id in the list. IF this argument is not specified, the default SpcCoeff and TauCoeff filenames are "SpcCoeff.bin" and "TauCoeff.bin" respectively.
UNITS: N/A
TYPE: CHARACTER(*)
DIMENSION: Same as output ChannelInfo argument
ATTRIBUTES: INTENT(IN), OPTIONAL

CloudCoeff_File: Name of the CRTM Binary format CloudCoeff file containing the scattering coefficient data. If not specified the default filename is "CloudCoeff.bin".
UNITS: N/A
TYPE: CHARACTER(*)
DIMENSION: Scalar
ATTRIBUTES: INTENT(IN), OPTIONAL

AerosolCoeff_File: Name of the CRTM Binary format AerosolCoeff file containing the aerosol absorption and scattering coefficient data. If not specified the default filename is "AerosolCoeff.bin".
UNITS: N/A
TYPE: CHARACTER(*)
DIMENSION: Scalar
ATTRIBUTES: INTENT(IN), OPTIONAL

EmisCoeff_File: Name of the CRTM Binary format EmisCoeff file containing the IRSSEM coefficient data. If not specified the default filename is "EmisCoeff.bin".
UNITS: N/A

```
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

    File_Path:      Character string specifying a file path for the
                    input data files. If not specified, the current
                    directory is the default.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

    Quiet:          Set this argument to suppress INFORMATION messages
                    being printed to standard output (or the message
                    log file if the Message_Log optional argument is
                    used.) By default, INFORMATION messages are printed.
                    If QUIET = 0, INFORMATION messages are OUTPUT.
                       QUIET = 1, INFORMATION messages are SUPPRESSED.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

    Process_ID:     Set this argument to the MPI process ID that this
                    function call is running under. This value is used
                    solely for controlling INFORMATIOn message output.
                    If MPI is not being used, ignore this argument.
                    This argument is ignored if the Quiet argument is set.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

    Output_Process_ID:
                    Set this argument to the MPI process ID in which
                    all INFORMATION messages are to be output. If
                    the passed Process_ID value agrees with this value
                    the INFORMATION messages are output.
                    This argument is ignored if the Quiet argument
                    is set.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

    Message_Log:    Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to the screen.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
```

```
      RCS_Id:             Character string containing the Revision Control
                          System Id field for the module.
                          UNITS:      N/A
                          TYPE:       CHARACTER(*)
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(OUT), OPTIONAL

FUNCTION RESULT:
      Error_Status:       The return value is an integer defining the error
                          status. The error codes are defined in the
                          Message_Handler module.
                          If == SUCCESS the CRTM initialisation was successful
                             == FAILURE an unrecoverable error occurred.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar

SIDE EFFECTS:
      All public data arrays accessed by this module and its dependencies
      are overwritten.

RESTRICTIONS:
      If specified, the length of the combined file path and filename strings
      cannot exceed 2000 characters.

COMMENTS:
      Note the INTENT on the output ChannelInfo argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```


4.2.2 *CRTM_Forward interface*

```
NAME:
      CRTM_Forward

PURPOSE:
      Function that calculates top-of-atmosphere (TOA) radiances
      and brightness temperatures for an input atmospheric profile or
      profile set and user specified satellites/channels.

CALLING SEQUENCE:
      Error_Status = CRTM_Forward( Atmosphere             , &
                                   Surface                , &
                                   GeometryInfo           , &
                                   ChannelInfo            , &
                                   RTSolution             , &
                                   Options    =Options    , &
                                   RCS_Id     =RCS_Id     , &
                                   Message_Log=Message_Log  )
```

```
INPUT ARGUMENTS:
      Atmosphere:     Structure containing the Atmosphere data.
                      UNITS:      N/A
                      TYPE:       CRTM_Atmosphere_type
                      DIMENSION:  Rank-1 (n_Profiles)
                      ATTRIBUTES: INTENT(IN)

      Surface:        Structure containing the Surface data.
                      UNITS:      N/A
                      TYPE:       CRTM_Surface_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN)

      GeometryInfo:   Structure containing the view geometry
                      information.
                      UNITS:      N/A
                      TYPE:       CRTM_GeometryInfo_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN)

      ChannelInfo:    Structure returned from the CRTM_Init() function
                      that contains the satellite/sensor channel index
                      information.
                      UNITS:      N/A
                      TYPE:       CRTM_ChannelInfo_type
                      DIMENSION:  Rank-1 (n_Sensors)
                      ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      RTSolution:     Structure containing the soluition to the RT equation
                      for the given inputs.
                      UNITS:      N/A
                      TYPE:       CRTM_RTSolution_type
                      DIMENSION:  Rank-2 (n_Channels x n_Profiles)
                      ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Options:        Options structure containing the optional arguments
                      for the CRTM.
                      UNITS:      N/A
                      TYPE:       CRTM_Options_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:    Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to the screen.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
```

```
      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(OUT), OPTIONAL

FUNCTION RESULT:
      Error_Status:   The return value is an integer defining the error status.
                      The error codes are defined in the Message_Handler module.
                      If == SUCCESS the computation was sucessful
                         == FAILURE an unrecoverable error occurred
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar

COMMENTS:
      - The Options optional input structure argument contains
        spectral information (e.g. emissivity) that must have the same
        spectral dimensionality (the "L" dimension) as the output
        RTSolution structure.

      - The INTENT on the output RTSolution argument is IN OUT rather
        than just OUT. This is necessary because the argument may be defined
        upon input. To prevent memory leaks, the IN OUT INTENT is a must.
```

4.2.3 *CRTM_Tangent_Linear interface*

```
NAME:
      CRTM_Tangent_Linear

PURPOSE:
      Function that calculates tangent-linear top-of-atmosphere (TOA)
      radiances and brightness temperatures for an input atmospheric
      profile or profile set and user specified satellites/channels.

CALLING SEQUENCE:
      Error_Status = CRTM_Tangent_Linear( Atmosphere             , &
                                          Surface                , &
                                          Atmosphere_TL          , &
                                          Surface_TL             , &
                                          GeometryInfo           , &
                                          ChannelInfo            , &
                                          RTSolution             , &
                                          RTSolution_TL          , &
                                          Options    =Options    , &
                                          RCS_Id     =RCS_Id     , &
                                          Message_Log=Message_Log  )

INPUT ARGUMENTS:
```

```
      Atmosphere:     Structure containing the Atmosphere data.
                      UNITS:      N/A
                      TYPE:       CRTM_Atmosphere_type
                      DIMENSION:  Rank-1 (n_Profiles)
                      ATTRIBUTES: INTENT(IN)

      Surface:        Structure containing the Surface data.
                      UNITS:      N/A
                      TYPE:       CRTM_Surface_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN)

      Atmosphere_TL:  Structure containing the tangent-linear Atmosphere data.
                      UNITS:      N/A
                      TYPE:       CRTM_Atmosphere_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN)

      Surface_TL:     Structure containing the tangent-linear Surface data.
                      UNITS:      N/A
                      TYPE:       CRTM_Surface_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN)

      GeometryInfo:   Structure containing the view geometry
                      information.
                      UNITS:      N/A
                      TYPE:       CRTM_GeometryInfo_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN)

      ChannelInfo:    Structure returned from the CRTM_Init() function
                      that contains the satellite/sensor channel index
                      information.
                      UNITS:      N/A
                      TYPE:       CRTM_ChannelInfo_type
                      DIMENSION:  Rank-1 (n_Sensors)
                      ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      RTSolution:     Structure containing the solution to the RT equation
                      for the given inputs.
                      UNITS:      N/A
                      TYPE:       CRTM_RTSolution_type
                      DIMENSION:  Rank-2 (n_Channels x n_Profiles)
                      ATTRIBUTES: INTENT(IN OUT)

      RTSolution_TL:  Structure containing the solution to the tangent-
                      linear RT equation for the given inputs.
                      UNITS:      N/A
                      TYPE:       CRTM_RTSolution_type
                      DIMENSION:  Rank-2 (n_Channels x n_Profiles)
                      ATTRIBUTES: INTENT(IN OUT)
```

```
OPTIONAL INPUT ARGUMENTS:
      Options:        Options structure containing the optional forward model
                      arguments for the CRTM.
                      UNITS:      N/A
                      TYPE:       CRTM_Options_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:    Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to the screen.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(OUT), OPTIONAL

FUNCTION RESULT:
      Error_Status:   The return value is an integer defining the error status.
                      The error codes are defined in the Message_Handler module.
                      If == SUCCESS the computation was sucessful
                         == FAILURE an unrecoverable error occurred
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar

COMMENTS:
      - The Options optional input structure arguments contain
        spectral information (e.g. emissivity) that must have the same
        spectral dimensionality (the "L" dimension) as the output
        RTSolution structures.

      - The INTENT on the output RTSolution arguments are IN OUT rather
        than just OUT. This is necessary because the arguments may be defined
        upon input. To prevent memory leaks, the IN OUT INTENT is a must.
```


4.2.4 *CRTM_Adjoint interface*

```
NAME:
      CRTM_Adjoint

PURPOSE:
```

```
      Function that calculates the adjoint of top-of-atmosphere (TOA)
      radiances and brightness temperatures for an input atmospheric
      profile or profile set and user specified satellites/channels.

CALLING SEQUENCE:
      Error_Status = CRTM_Adjoint( Atmosphere             , &
                                   Surface                , &
                                   RTSolution_AD          , &
                                   GeometryInfo           , &
                                   ChannelInfo            , &
                                   Atmosphere_AD          , &
                                   Surface_AD             , &
                                   RTSolution             , &
                                   Options    =Options    , &
                                   RCS_Id     =RCS_Id     , &
                                   Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Atmosphere:     Structure containing the Atmosphere data.
                      UNITS:      N/A
                      TYPE:       CRTM_Atmosphere_type
                      DIMENSION:  Rank-1 (n_Profiles)
                      ATTRIBUTES: INTENT(IN)

      Surface:        Structure containing the Surface data.
                      UNITS:      N/A
                      TYPE:       CRTM_Surface_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN)

      RTSolution_AD:  Structure containing the RT solution adjoint inputs.
                      **NOTE: On EXIT from this function, the contents of
                              this structure may be modified (e.g. set to
                              zero.)
                      UNITS:      N/A
                      TYPE:       CRTM_RTSolution_type
                      DIMENSION:  Rank-2 (n_Channels x n_Profiles)
                      ATTRIBUTES: INTENT(IN OUT)

      GeometryInfo:   Structure containing the view geometry
                      information.
                      UNITS:      N/A
                      TYPE:       CRTM_GeometryInfo_type
                      DIMENSION:  Same as input Atmosphere argument
                      ATTRIBUTES: INTENT(IN)

      ChannelInfo:    Structure returned from the CRTM_Init() function
                      that contains the satellite/sensor channel index
                      information.
                      UNITS:      N/A
                      TYPE:       CRTM_ChannelInfo_type
                      DIMENSION:  Rank-1 (n_Sensors)
                      ATTRIBUTES: INTENT(IN)
```

```
OPTIONAL INPUT ARGUMENTS:
      Options:        Options structure containing the optional forward model
                      arguments for the CRTM.
                      UNITS:      N/A
                      TYPE:       CRTM_Options_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:    Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to the screen.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

OUTPUT ARGUMENTS:
      Atmosphere_AD:  Structure containing the adjoint Atmosphere data.
                      **NOTE: On ENTRY to this function, the contents of
                              this structure should be defined (e.g.
                              initialized to some value based on the
                              position of this function in the call chain.)
                      UNITS:      N/A
                      TYPE:       CRTM_Atmosphere_type
                      DIMENSION:  Same as input Atmosphere argument
                      ATTRIBUTES: INTENT(IN OUT)

      Surface_AD:     Structure containing the tangent-linear Surface data.
                      **NOTE: On ENTRY to this function, the contents of
                              this structure should be defined (e.g.
                              initialized to some value based on the
                              position of this function in the call chain.)
                      UNITS:      N/A
                      TYPE:       CRTM_Surface_type
                      DIMENSION:  Same as input Atmosphere argument
                      ATTRIBUTES: INTENT(IN OUT)

      RTSolution:     Structure containing the solution to the RT equation
                      for the given inputs.
                      UNITS:      N/A
                      TYPE:       CRTM_RTSolution_type
                      DIMENSION:  Same as input RTSolution_AD argument
                      ATTRIBUTES: INTENT(IN OUT)

OPTIONAL OUTPUT ARGUMENTS:
      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(OUT), OPTIONAL

FUNCTION RESULT:
```

```
      Error_Status:   The return value is an integer defining the error status.
                      The error codes are defined in the Message_Handler module.
                      If == SUCCESS the computation was sucessful
                         == FAILURE an unrecoverable error occurred
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar

SIDE EFFECTS:
     Note that the input adjoint arguments are modified upon exit, and
     the output adjoint arguments must be defined upon entry. This is
     a consequence of the adjoint formulation where, effectively, the
     chain rule is being used and this function could reside anywhere
     in the chain of derivative terms.

COMMENTS:
      - The Options optional structure arguments contain
        spectral information (e.g. emissivity) that must have the same
        spectral dimensionality (the "L" dimension) as the RTSolution
        structures.

      - The INTENT on the output RTSolution, Atmosphere_AD, and
        Surface_AD arguments are IN OUT rather than just OUT. This is
        necessary because the arguments should be defined upon input.
        To prevent memory leaks, the IN OUT INTENT is a must.
```

4.2.5 *CRTM_K_Matrix interface*

```
NAME:
      CRTM_K_Matrix

PURPOSE:
      Function that calculates the K-matrix of top-of-atmosphere (TOA)
      radiances and brightness temperatures for an input atmospheric
      profile or profile set and user specified satellites/channels.

CALLING SEQUENCE:
      Error_Status = CRTM_K_Matrix( Atmosphere             , &
                                    Surface                , &
                                    RTSolution_K           , &
                                    GeometryInfo           , &
                                    ChannelInfo            , &
                                    Atmosphere_K           , &
                                    Surface_K              , &
                                    RTSolution             , &
                                    Options    =Options    , &
                                    RCS_Id     =RCS_Id     , &
                                    Message_Log=Message_Log  )

INPUT ARGUMENTS:
```

```
      Atmosphere:     Structure containing the Atmosphere data.
                      UNITS:      N/A
                      TYPE:       CRTM_Atmosphere_type
                      DIMENSION:  Rank-1 (n_Profiles)
                      ATTRIBUTES: INTENT(IN)

      Surface:        Structure containing the Surface data.
                      UNITS:      N/A
                      TYPE:       CRTM_Surface_type
                      DIMENSION:  Same as input Atmosphere argument.
                      ATTRIBUTES: INTENT(IN)

      RTSolution_K:   Structure containing the RT solution K-matrix inputs.
                      **NOTE: On EXIT from this function, the contents of
                              this structure may be modified (e.g. set to
                              zero.)
                      UNITS:      N/A
                      TYPE:       CRTM_RTSolution_type
                      DIMENSION:  Rank-2 (n_Channels x n_Profiles)
                      ATTRIBUTES: INTENT(IN OUT)

      GeometryInfo:   Structure containing the view geometry
                      information.
                      UNITS:      N/A
                      TYPE:       CRTM_GeometryInfo_type
                      DIMENSION:  Same as input Atmosphere argument
                      ATTRIBUTES: INTENT(IN)

      ChannelInfo:    Structure returned from the CRTM_Init() function
                      that contains the satellite/sesnor channel index
                      information.
                      UNITS:      N/A
                      TYPE:       CRTM_ChannelInfo_type
                      DIMENSION:  Rank-1 (n_Sensors)
                      ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Options:        Options structure containing the optional forward model
                      arguments for the CRTM.
                      UNITS:      N/A
                      TYPE:       CRTM_Options_type
                      DIMENSION:  Same as input Atmosphere structure
                      ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:    Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to the screen.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

OUTPUT ARGUMENTS:
```

```
      Atmosphere_K:   Structure containing the K-matrix Atmosphere data.
                      **NOTE: On ENTRY to this function, the contents of
                              this structure should be defined (e.g.
                              initialized to some value based on the
                              position of this function in the call chain.)
                      UNITS:      N/A
                      TYPE:       CRTM_Atmosphere_type
                      DIMENSION:  Same as input RTSolution_K argument
                      ATTRIBUTES: INTENT(IN OUT)

      Surface_K:      Structure containing the tangent-linear Surface data.
                      **NOTE: On ENTRY to this function, the contents of
                              this structure should be defined (e.g.
                              initialized to some value based on the
                              position of this function in the call chain.)
                      UNITS:      N/A
                      TYPE:       CRTM_Surface_type
                      DIMENSION:  Same as input RTSolution_K argument
                      ATTRIBUTES: INTENT(IN OUT)

      RTSolution:     Structure containing the solution to the RT equation
                      for the given inputs.
                      UNITS:      N/A
                      TYPE:       CRTM_RTSolution_type
                      DIMENSION:  Same as input RTSolution_K argument
                      ATTRIBUTES: INTENT(IN OUT)

OPTIONAL OUTPUT ARGUMENTS:
      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(OUT), OPTIONAL

FUNCTION RESULT:
      Error_Status:   The return value is an integer defining the error status.
                      The error codes are defined in the Message_Handler module.
                      If == SUCCESS the computation was sucessful
                         == FAILURE an unrecoverable error occurred
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar

SIDE EFFECTS:
     Note that the input K-matrix arguments are modified upon exit, and
     the output K-matrix arguments must be defined upon entry. This is
     a consequence of the K-matrix formulation where, effectively, the
     chain rule is being used and this funtion could reside anywhere
     in the chain of derivative terms.

COMMENTS:
      - The Options optional structure arguments contain
        spectral information (e.g. emissivity) that must have the same
```

```
      spectral dimensionality (the "L" dimension) as the RTSolution
      structures.

    - The INTENT on the output RTSolution, Atmosphere_K, and Surface_K,
      arguments are IN OUT rather than just OUT. This is necessary because
      the arguments should be defined upon input. To prevent memory leaks,
      the IN OUT INTENT is a must.
```

4.2.6 *CRTM_Destroy interface*

```
NAME:
      CRTM_Destroy

PURPOSE:
      Function to deallocate all the shared data arrays allocated and
      populated during the CRTM initialization.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy( ChannelInfo           , &
                                   Process_ID =Process_ID , &
                                   RCS_Id     =RCS_Id     , &
                                   Message_Log=Message_Log  )

OUTPUT ARGUMENTS:
      ChannelInfo:  Reinitialized ChannelInfo structure.
                    UNITS:      N/A
                    TYPE:       CRTM_ChannelInfo_type
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Process_ID:   Set this argument to the MPI process ID that this
                    function call is running under. This value is used
                    solely for controlling message output. If MPI is not
                    being used, ignore this argument.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to the screen.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
```

```
      RCS_Id:       Character string containing the Revision Control
                    System Id field for for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(OUT), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error
                    status. The error codes are defined in the
                    Message_Handler module.
                    If == SUCCESS the CRTM deallocations were successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

SIDE EFFECTS:
      All CRTM shared data arrays and structures are deallocated.

COMMENTS:
      Note the INTENT on the output ChannelInfo argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A
Structure and procedure interface definitions

A.1 ChannelInfo Structure

```
TYPE :: CRTM_ChannelInfo_type
  INTEGER :: n_Allocates = 0
  ! Dimensions
  INTEGER :: n_Channels = 0  ! L dimension
  ! Scalar data
  CHARACTER(STRLEN) :: Sensor_ID        = ' '
  INTEGER           :: WMO_Satellite_ID = INVALID_WMO_SATELLITE_ID
  INTEGER           :: WMO_Sensor_ID    = INVALID_WMO_SENSOR_ID
  INTEGER           :: Sensor_Index     = 0
  ! Array data
  INTEGER, POINTER :: Sensor_Channel(:) => NULL()  ! L
  INTEGER, POINTER :: Channel_Index(:)  => NULL()  ! L
END TYPE CRTM_ChannelInfo_type
```

Figure A.1: CRTM_ChannelInfo_type structure definition.

A.1.1 CRTM_Associated_ChannelInfo interface

```
NAME:
      CRTM_Associated_ChannelInfo

PURPOSE:
      Function to test the association status of the pointer members of a
      CRTM ChannelInfo structure.

CALLING SEQUENCE:
      Association_Status = CRTM_Associated_ChannelInfo( ChannelInfo      , &
                                                        ANY_Test=Any_Test  )

INPUT ARGUMENTS:
      ChannelInfo: ChannelInfo structure which is to have its pointer
                   member's association status tested.
                   UNITS:      N/A
                   TYPE:       CRTM_ChannelInfo_type
                   DIMENSION:  Scalar OR Rank-1 array
                   ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ANY_Test:    Set this argument to test if ANY of the
                   ChannelInfo structure pointer members are associated.
                   The default is to test if ALL the pointer members
                   are associated.
                   If ANY_Test = 0, test if ALL the pointer members
                                    are associated.  (DEFAULT)
                      ANY_Test = 1, test if ANY of the pointer members
                                    are associated.

FUNCTION RESULT:
```

```
      Association_Status:  The return value is a logical value indicating the
                           association status of the ChannelInfo pointer
                           members.
                           .TRUE.  - if ALL the ChannelInfo pointer members
                                     are associated, or if the ANY_Test argument
                                     is set and ANY of the ChannelInfo
                                     pointer members are associated.
                           .FALSE. - some or all of the ChannelInfo pointer
                                     members are NOT associated.
                           UNITS:      N/A
                           TYPE:       LOGICAL
                           DIMENSION:  Same as input ChannelInfo argument
```

A.1.2 CRTM_Allocate_ChannelInfo interface


```
NAME:
      CRTM_Allocate_ChannelInfo

PURPOSE:
      Function to allocate the pointer members of a CRTM ChannelInfo
      data structure.

CALLING SEQUENCE:
      Error_Status = CRTM_Allocate_ChannelInfo( n_Channels             , &
                                                ChannelInfo            , &
                                                Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Channels:   The number of channels in the ChannelInfo structure.
                    Must be > 0.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar or Rank-1 array
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      ChannelInfo:  ChannelInfo structure with allocated pointer members
                    UNITS:      N/A
                    TYPE:       CRTM_ChannelInfo_type
                    DIMENSION:  Same as input n_Channels argument
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    Messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output Messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
```

```
                  ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the ERROR_HANDLER module.
                    If == SUCCESS the structure pointer allocations were
                                  successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to one (1) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output ChannelInfo argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.1.3 CRTM_Destroy_ChannelInfo interface

```
NAME:
      CRTM_Destroy_ChannelInfo

PURPOSE:
      Function to re-initialize the scalar and pointer members of a CRTM
      ChannelInfo data structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy_ChannelInfo( ChannelInfo            , &
                                               Message_Log=Message_Log  )

OUTPUT ARGUMENTS:
      ChannelInfo:  Re-initialized ChannelInfo structure.
                    UNITS:      N/A
                    TYPE:       CRTM_ChannelInfo_type
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    Messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output Messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
```

```
                  ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the ERROR_HANDLER module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to zero (0) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output ChannelInfo argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.1.4 CRTM_Assign_ChannelInfo interface

```
NAME:
      CRTM_Assign_ChannelInfo

PURPOSE:
      Function to copy valid CRTM ChannelInfo structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Assign_ChannelInfo( ChannelInfo_in         , &
                                              ChannelInfo_out        , &
                                              Message_Log=Message_Log  )

INPUT ARGUMENTS:
      ChannelInfo_in:  ChannelInfo structure which is to be copied.
                       UNITS:      N/A
                       TYPE:       CRTM_ChannelInfo_type
                       DIMENSION:  Scalar OR Rank-1 array
                       ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      ChannelInfo_out: Copy of the input structure, ChannelInfo_in.
                       UNITS:      N/A
                       TYPE:       CRTM_ChannelInfo_type
                       DIMENSION:  Same as ChannelInfo_in argument
                       ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:     Character string specifying a filename in which any
```

```
                        Messages will be logged. If not specified, or if an
                        error occurs opening the log file, the default action
                        is to output Messages to standard output.
                        UNITS:      N/A
                        TYPE:       CHARACTER(*)
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

  FUNCTION RESULT:
        Error_Status:   The return value is an integer defining the error status.
                        The error codes are defined in the ERROR_HANDLER module.
                        If == SUCCESS the structure assignment was successful
                           == FAILURE an error occurred
                        UNITS:      N/A
                        TYPE:       INTEGER
                        DIMENSION:  Scalar

  COMMENTS:
        Note the INTENT on the output ChannelInfo argument is IN OUT rather than
        just OUT. This is necessary because the argument may be defined upon
        input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.1.5 CRTM_Equal_ChannelInfo interface

```
  NAME:
        CRTM_Equal_ChannelInfo

  PURPOSE:
        Function to test if two ChannelInfo structures are equal.

  CALLING SEQUENCE:
        Error_Status = CRTM_Equal_ChannelInfo( ChannelInfo_LHS        , &
                                               ChannelInfo_RHS        , &
                                               ULP_Scale  =ULP_Scale  , &
                                               Check_All  =Check_All  , &
                                               Message_Log=Message_Log  )


  INPUT ARGUMENTS:
        ChannelInfo_LHS: ChannelInfo structure to be compared; equivalent
                         to the left-hand side of a lexical comparison, e.g.
                           IF ( ChannelInfo_LHS == ChannelInfo_RHS ).
                         UNITS:      N/A
                         TYPE:       CRTM_ChannelInfo_type
                         DIMENSION:  Scalar OR Rank-1 array
                         ATTRIBUTES: INTENT(IN)

        ChannelInfo_RHS: ChannelInfo structure to be compared to; equivalent
                         to the right-hand side of a lexical comparison, e.g.
                           IF ( ChannelInfo_LHS == ChannelInfo_RHS ).
```

```
                    UNITS:      N/A
                    TYPE:       CRTM_ChannelInfo_type
                    DIMENSION:  Same as ChannelInfo_LHS argument
                    ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ULP_Scale:    Unit of data precision used to scale the floating
                    point comparison. ULP stands for "Unit in the Last Place,"
                    the smallest possible increment or decrement that can be
                    made using a machine's floating point arithmetic.
                    Value must be positive - if a negative value is supplied,
                    the absolute value is used. If not specified, the default
                    value is 1.
                    ** NOTE: This is a hook for future changes and is not used.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

      Check_All:    Set this argument to check ALL the floating point
                    channel data of the ChannelInfo structures. The default
                    action is return with a FAILURE status as soon as
                    any difference is found. This optional argument can
                    be used to get a listing of ALL the differences
                    between data in ChannelInfo structures.
                    If == 0, Return with FAILURE status as soon as
                             ANY difference is found  *DEFAULT*
                       == 1, Set FAILURE status if ANY difference is
                             found, but continue to check ALL data.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      None
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structures were equal
                       == FAILURE - an error occurred, or
                                  - the structures were different.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
```

A.1.6 *CRTM_nChannels_ChannelInfo interface*

```
NAME:
      CRTM_nChannels_ChannelInfo

PURPOSE:
      Function to return the number of channels defined in a ChannelInfo
      structure or structure array

CALLING SEQUENCE:
      nChannels = CRTM_nChannels_ChannelInfo( ChannelInfo )

INPUT ARGUMENTS:
      ChannelInfo: ChannelInfo structure or structure which is to have its
                   channels counted.
                   UNITS:      N/A
                   TYPE:       CRTM_ChannelInfo_type
                   DIMENSION:  Scalar
                                 or
                               Rank-1
                   ATTRIBUTES: INTENT(IN)

FUNCTION RESULT:
      nChannels:   The number of defined channels in the input argument.
                   UNITS:      N/A
                   TYPE:       INTEGER
                   DIMENSION:  Scalar
```


A.1.7 *CRTM_RCS_ID_ChannelInfo interface*

```
NAME:
      CRTM_RCS_ID_ChannelInfo

PURPOSE:
      Subroutine to return the module RCS Id information.

CALLING SEQUENCE:
      CALL CRTM_RCS_Id_ChannelInfo( RCS_Id )

OUTPUT ARGUMENTS:
      RCS_Id:        Character string containing the Revision Control
                     System Id field for the module.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(OUT)
```

A.2 `Atmosphere` Structure

```
TYPE :: CRTM_Atmosphere_type
  INTEGER :: n_Allocates = 0
  ! Dimension values
  INTEGER :: Max_Layers   = 0  ! K dimension
  INTEGER :: n_Layers     = 0  ! Kuse dimension
  INTEGER :: n_Absorbers  = 0  ! J dimension
  INTEGER :: Max_Clouds   = 0  ! Nc dimension
  INTEGER :: n_Clouds     = 0  ! NcUse dimension
  INTEGER :: Max_Aerosols = 0  ! Na dimension
  INTEGER :: n_Aerosols   = 0  ! NaUse dimension
  ! Number of added layers
  INTEGER :: n_Added_Layers = 0
  ! Climatology model associated with the profile
  INTEGER :: Climatology = INVALID_MODEL
  ! Absorber ID and units
  INTEGER, POINTER :: Absorber_ID(:)    => NULL() ! J
  INTEGER, POINTER :: Absorber_Units(:) => NULL() ! J
  ! Profile LEVEL and LAYER quantities
  REAL(fp), POINTER :: Level_Pressure(:) => NULL()  ! 0:K
  REAL(fp), POINTER :: Pressure(:)       => NULL()  ! K
  REAL(fp), POINTER :: Temperature(:)    => NULL()  ! K
  REAL(fp), POINTER :: Absorber(:,:)     => NULL()  ! K x J
  ! Clouds associated with each profile
  TYPE(CRTM_Cloud_type),   POINTER :: Cloud(:)   => NULL()  ! Nc
  ! Aerosols associated with each profile
  TYPE(CRTM_Aerosol_type), POINTER :: Aerosol(:) => NULL()  ! Na
END TYPE CRTM_Atmosphere_type
```

Figure A.2: CRTM_Atmosphere_type structure definition.

Climatology Type	Parameter
Tropical	`TROPICAL`
Midlatitude summer	`MIDLATITUDE_SUMMER`
Midlatitude winter	`MIDLATITUDE_WINTER`
Subarctic summer	`SUBARCTIC_SUMMER`
Subarctic winter	`SUBARCTIC_WINTER`
U.S. Standard Atmosphere	`US_STANDARD_ATMOSPHERE`

Table A.1: CRTM `Atmosphere` structure valid `Climatology` definitions. The same set as defined for LBLRTM is used.

Molecule	Parameter	Molecule	Parameter
H_2O	H2O_ID	HI	HI_ID
CO_2	CO2_ID	ClO	ClO_ID
O_3	O3_ID	OCS	OCS_ID
N_2O	N2O_ID	H_2CO	H2CO_ID
CO	CO_ID	HOCl	HOCl_ID
CH_4	CH4_ID	N_2	N2_ID
O_2	O2_ID	HCN	HCN_ID
NO	NO_ID	CH_3l	CH3l_ID
SO_2	SO2_ID	H_2O_2	H2O2_ID
NO_2	NO2_ID	C_2H_2	C2H2_ID
NH_3	NH3_ID	C_2H_6	C2H6_ID
HNO_3	HNO3_ID	PH_3	PH3_ID
OH	OH_ID	COF_2	COF2_ID
HF	HF_ID	SF_6	SF6_ID
HCl	HCl_ID	H_2S	H2S_ID
HBr	HBr_ID	HCOOH	HCOOH_ID

Table A.2: CRTM `Atmosphere` structure valid `Absorber_ID` definitions. The same molecule set as defined for HITRAN is used.

Units	Parameter
Volume mixing ratio, ppmv	VOLUME_MIXING_RATIO_UNITS
Number density, cm^{-3}	NUMBER_DENSITY_UNITS
Mass mixing ratio, g/kg	MASS_MIXING_RATIO_UNITS
Mass density, $g.m^{-3}$	MASS_DENSITY_UNITS
Partial pressure, hPa	PARTIAL_PRESSURE_UNITS
Dewpoint temperature, K **(H_2O ONLY)**	DEWPOINT_TEMPERATURE_K_UNITS
Dewpoint temperature, C **(H_2O ONLY)**	DEWPOINT_TEMPERATURE_C_UNITS
Relative humidity, % **(H_2O ONLY)**	RELATIVE_HUMIDITY_UNITS
Specific amount, g/g	SPECIFIC_AMOUNT_UNITS
Integrated path, mm	INTEGRATED_PATH_UNITS

Table A.3: CRTM `Atmosphere` structure valid `Absorber_Units` definitions. The same set as defined for LBLRTM is used.

A.2.1 CRTM_Associated_Atmosphere interface

```
NAME:
      CRTM_Associated_Atmosphere

PURPOSE:
      Function to test the association status of the components of a
      CRTM Atmosphere structure.

CALLING SEQUENCE:
      Association_Status = CRTM_Associated_Atmosphere( Atmosphere               , &
                                                       ANY_Test    =Any_Test    , &
                                                       Skip_Cloud  =Skip_Cloud  , &
                                                       Skip_Aerosol=Skip_Aerosol  )

INPUT ARGUMENTS:
      Atmosphere:          Structure which is to have its pointer
                           member's association status tested.
                           UNITS:      N/A
                           TYPE:       CRTM_Atmosphere_type
                           DIMENSION:  Scalar, Rank-1, OR Rank-2 array
                           ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ANY_Test:            Set this argument to test if ANY of the
                           Atmosphere structure components are associated.
                           The default is to test if ALL the components
                           are associated.
                           If ANY_Test = 0, test if ALL the components
                                            are associated.  (DEFAULT)
                              ANY_Test = 1, test if ANY of the components
                                            are associated.
                           UNITS:      N/A
                           TYPE:       INTEGER
                           DIMENSION:  Scalar
                           ATTRIBUTES: INTENT(IN), OPTIONAL

      Skip_Cloud:          Set this argument to not include the Cloud
                           member in the association test. This is required
                           because a valid Atmosphere structure can be
                           cloud-free.
                           If Skip_Cloud = 0, the Cloud member association
                                              status is tested.  (DEFAULT)
                              Skip_Cloud = 1, the Cloud member association
                                              status is NOT tested.
                           UNITS:      N/A
                           TYPE:       INTEGER
                           DIMENSION:  Scalar
                           ATTRIBUTES: INTENT(IN), OPTIONAL

      Skip_Aerosol:        Set this argument to not include the Aerosol
                           member in the association test. This is required
                           because a valid Atmosphere structure can be
```

```
                        aerosol-free.
                        If Skip_Aerosol = 0, the Aerosol member association
                                             status is tested.  (DEFAULT)
                           Skip_Aerosol = 1, the Aerosol member association
                                             status is NOT tested.
                        UNITS:      N/A
                        TYPE:       INTEGER
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

  FUNCTION RESULT:
        Association_Status:  The return value is a logical value indicating the
                             association status of the Atmosphere components.
                             .TRUE.  - if ALL the Atmosphere components are
                                       associated, or if the ANY_Test argument
                                       is set and ANY of the Atmosphere pointer
                                       members are associated.
                             .FALSE. - some or all of the Atmosphere pointer
                                       members are NOT associated.
                             UNITS:      N/A
                             TYPE:       LOGICAL
                             DIMENSION:  Same as input Atmosphere argument
```

A.2.2 CRTM_Allocate_Atmosphere interface

```
  NAME:
        CRTM_Allocate_Atmosphere

  PURPOSE:
        Function to allocate CRTM Atmosphere data structures.

  CALLING SEQUENCE:
        Error_Status = CRTM_Allocate_Atmosphere( n_Layers               , &
                                                 n_Absorbers            , &
                                                 n_Clouds               , &
                                                 n_Aerosols             , &
                                                 Atmosphere             , &
                                                 Message_Log=Message_Log  )

  INPUT ARGUMENTS:
        n_Layers:     Number of layers dimension.
                      Must be > 0.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar OR Rank-1
                                  See output Atmosphere dimensionality chart
                      ATTRIBUTES: INTENT(IN)

        n_Absorbers:  Number of absorbers dimension. This will be the same for
                      all elements if the Atmosphere argument is an array.
```

```
                  Must be > 0.
                  UNITS:      N/A
                  TYPE:       INTEGER
                  DIMENSION:  Scalar
                  ATTRIBUTES: INTENT(IN)

      n_Clouds:   Number of clouds dimension of Atmosphere data.
                  ** Note: Can be = 0 (i.e. clear sky). **
                  UNITS:      N/A
                  TYPE:       INTEGER
                  DIMENSION:  Scalar OR Rank-1
                              See output Atmosphere dimensionality chart
                  ATTRIBUTES: INTENT(IN)

      n_Aerosols: Number of aerosol types dimension of Atmosphere data.
                  ** Note: Can be = 0 (i.e. no aerosols). **
                  UNITS:      N/A
                  TYPE:       INTEGER
                  DIMENSION:  Scalar OR Rank-1
                              See output Atmosphere dimensionality chart
                  ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Message_Log: Character string specifying a filename in which any
                   messages will be logged. If not specified, or if an
                   error occurs opening the log file, the default action
                   is to output messages to standard output.
                   UNITS:      N/A
                   TYPE:       CHARACTER(*)
                   DIMENSION:  Scalar
                   ATTRIBUTES: INTENT(IN), OPTIONAL

OUTPUT ARGUMENTS:
      Atmosphere:  Atmosphere structure with allocated components. The
                   following table shows the allowable dimension combinations
                   for the calling routine, where M == number of profiles:

                      Input       Input       Input      Input        Output
                    n_Layers   n_Absorbers  n_Clouds  n_Aerosols    Atmosphere
                    dimension   dimension   dimension  dimension    dimension
                   ------------------------------------------------------------
                      scalar      scalar      scalar     scalar       scalar
                      scalar      scalar      scalar     scalar         M
                      scalar      scalar      scalar       M            M
                      scalar      scalar        M        scalar         M
                      scalar      scalar        M          M            M
                        M         scalar      scalar     scalar         M
                        M         scalar      scalar       M            M
                        M         scalar        M        scalar         M
                        M         scalar        M          M            M

                   Note the number of absorbers cannot vary with the profile.

                   These multiple interfaces are supplied purely for ease of
```

```
                  use depending on what data is available.

                  UNITS:      N/A
                  TYPE:       CRTM_Atmosphere_type
                  DIMENSION:  Scalar or Rank-1
                              See chart above.
                  ATTRIBUTES: INTENT(IN OUT)


FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to one (1) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Atmosphere argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.2.3 CRTM_Destroy_Atmosphere interface

```
NAME:
      CRTM_Destroy_Atmosphere

PURPOSE:
      Function to re-initialize CRTM Atmosphere data structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy_Atmosphere( Atmosphere             , &
                                              Message_Log=Message_Log  )

OUTPUT ARGUMENTS:
      Atmosphere:   Re-initialized Atmosphere structure. In the context of
                    the CRTM, rank-1 corresponds to an vector of profiles,
                    and rank-2 corresponds to an array of channels x profiles.
                    The latter is used in the K-matrix model.
                    UNITS:      N/A
                    TYPE:       CRTM_Atmosphere_type
                    DIMENSION:  Scalar, Rank-1, OR Rank-2 array
                    ATTRIBUTES: INTENT(IN OUT)
```

```
OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to zero (0) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Atmosphere argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.2.4 CRTM_Assign_Atmosphere interface

```
NAME:
      CRTM_Assign_Atmosphere

PURPOSE:
      Function to copy valid CRTM Atmosphere structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Assign_Atmosphere( Atmosphere_in          , &
                                             Atmosphere_out         , &
                                             Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Atmosphere_in:   Atmosphere structure which is to be copied. In the
                       context of the CRTM, rank-1 corresponds to an vector
                       of profiles, and rank-2 corresponds to an array of
                       channels x profiles. The latter is used in the K-matrix
                       model.
                       UNITS:      N/A
                       TYPE:       CRTM_Atmosphere_type
```

```
                        DIMENSION:  Scalar, Rank-1, or Rank-2 array
                        ATTRIBUTES: INTENT(IN)

  OUTPUT ARGUMENTS:
        Atmosphere_out:  Copy of the input structure, Atmosphere_in.
                         UNITS:      N/A
                         TYPE:       CRTM_Atmosphere_type
                         DIMENSION:  Same as Atmosphere_in
                         ATTRIBUTES: INTENT(IN OUT)

  OPTIONAL INPUT ARGUMENTS:
        Message_Log:     Character string specifying a filename in which any
                         messages will be logged. If not specified, or if an
                         error occurs opening the log file, the default action
                         is to output messages to standard output.
                         UNITS:      N/A
                         TYPE:       CHARACTER(*)
                         DIMENSION:  Scalar
                         ATTRIBUTES: INTENT(IN), OPTIONAL

  FUNCTION RESULT:
        Error_Status:    The return value is an integer defining the error status.
                         The error codes are defined in the Message_Handler module.
                         If == SUCCESS the structure assignment was successful
                            == FAILURE an error occurred
                         UNITS:      N/A
                         TYPE:       INTEGER
                         DIMENSION:  Scalar

  COMMENTS:
        Note the INTENT on the output Atmosphere argument is IN OUT rather than
        just OUT. This is necessary because the argument may be defined upon
        input. To prevent memory leaks, the IN OUT INTENT is a must.
```


A.2.5 CRTM_Equal_Atmosphere interface

```
  NAME:
        CRTM_Equal_Atmosphere

  PURPOSE:
        Function to test if two Atmosphere structures are equal.

  CALLING SEQUENCE:
        Error_Status = CRTM_Equal_Atmosphere( Atmosphere_LHS                      , &
                                              Atmosphere_RHS                      , &
                                              ULP_Scale         =ULP_Scale        , &
                                              Percent_Difference=Percent_Difference, &
                                              Check_All         =Check_All        , &
                                              Message_Log       =Message_Log        )
```

```
INPUT ARGUMENTS:
      Atmosphere_LHS:     Atmosphere structure to be compared; equivalent to the
                          left-hand side of a lexical comparison, e.g.
                            IF ( Atmosphere_LHS == Atmosphere_RHS ).
                          In the context of the CRTM, rank-1 corresponds to an
                          vector of profiles, and rank-2 corresponds to an array
                          of channels x profiles. The latter is used in the
                          K-matrix model.
                          UNITS:      N/A
                          TYPE:       CRTM_Atmosphere_type
                          DIMENSION:  Scalar, Rank-1, or Rank-2 array
                          ATTRIBUTES: INTENT(IN)

      Atmosphere_RHS:     Atmosphere structure to be compared to; equivalent to
                          right-hand side of a lexical comparison, e.g.
                            IF ( Atmosphere_LHS == Atmosphere_RHS ).
                          UNITS:      N/A
                          TYPE:       CRTM_Atmosphere_type
                          DIMENSION:  Same as Atmosphere_LHS
                          ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ULP_Scale:          Unit of data precision used to scale the floating
                          point comparison. ULP stands for "Unit in the Last Place,"
                          the smallest possible increment or decrement that can be
                          made using a machine's floating point arithmetic.
                          Value must be positive - if a negative value is supplied,
                          the absolute value is used. If not specified, the default
                          value is 1.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

      Percent_Differnece: Percentage difference value to use in comparing
                          the numbers rather than testing within some numerical
                          limit. The ULP_Scale argument is ignored if this argument is
                          specified.
                          UNITS:      N/A
                          TYPE:       REAL(fp)
                          DIMENSION:  Scalar
                          ATTRIBUTES: OPTIONAL, INTENT(IN)

      Check_All:          Set this argument to check ALL the floating point
                          channel data of the Atmosphere structures. The default
                          action is return with a FAILURE status as soon as
                          any difference is found. This optional argument can
                          be used to get a listing of ALL the differences
                          between data in Atmosphere structures.
                          If == 0, Return with FAILURE status as soon as
                                   ANY difference is found  *DEFAULT*
                             == 1, Set FAILURE status if ANY difference is
                                   found, but continue to check ALL data.
```

```
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:        Character string specifying a filename in which any
                          messages will be logged. If not specified, or if an
                          error occurs opening the log file, the default action
                          is to output messages to standard output.
                          UNITS:      None
                          TYPE:       CHARACTER(*)
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:       The return value is an integer defining the error status.
                          The error codes are defined in the Message_Handler module.
                          If == SUCCESS the structures were equal
                             == FAILURE - an error occurred, or
                                        - the structures were different.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
```

A.2.6 CRTM_SetLayers_Atmosphere interface

```
NAME:
      CRTM_SetLayers_Atmosphere

PURPOSE:
      Function to set the number of layers to use in a CRTM Atmosphere
      structure.

CALLING SEQUENCE:
      Error_Status = CRTM_SetLayers_Atmosphere( n_Layers               , &
                                                Atmosphere             , &
                                                Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Layers:     The value to set the n_Layers component of the
                    Atmosphere structure, as well as any of its
                    Cloud or Aerosol structure components.
                    UNITS:      N/A
                    TYPE:       CRTM_Atmosphere_type
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

      Atmosphere:   Atmosphere structure in which the n_Layers dimension
                    is to be updated.
                    UNITS:      N/A
```

```
                    TYPE:       CRTM_Atmosphere_type
                    DIMENSION:  Scalar, Rank-1, or Rank-2 array
                    ATTRIBUTES: INTENT(IN OUT)
OUTPUT ARGUMENTS:
      Atmosphere:   On output, the atmosphere structure with the updated
                    n_Layers dimension.
                    UNITS:      N/A
                    TYPE:       CRTM_Atmosphere_type
                    DIMENSION:  Scalar, Rank-1, or Rank-2 array
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      None
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the layer reset was successful
                       == FAILURE an error occurred
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

SIDE EFFECTS:
      The argument Atmosphere is INTENT(IN OUT) and is modified upon output.

COMMENTS:
      - Note that the n_Layers input is *ALWAYS* scalar. Thus, all Atmosphere
        elements will be set to the same number of layers.

      - If n_Layers <= Atmosphere%Max_Layers, then only the dimension value
        of the structure and any sub-structures are changed.

      - If n_Layers > Atmosphere%Max_Layers, then the entire structure is
        reallocated to the required number of layers. No other dimensions
        of the structure or substructures are altered.
```

A.2.7 CRTM_Sum_Atmosphere interface

```
NAME:
      CRTM_Sum_Atmosphere

PURPOSE:
```

```
      Function to perform a sum of two valid CRTM Atmosphere structures. The
      summation performed is:
        A = A + Scale_Factor*B + Offset
      where A and B are the CRTM Atmosphere structures, and Scale_Factor and
      Offset are optional weighting factors.

CALLING SEQUENCE:
      Error_Status = CRTM_Sum_Atmosphere( A                         , &
                                          B                         , &
                                          Scale_Factor=Scale_Factor, &
                                          Offset      =Offset       , &
                                          Message_Log =Message_Log    )

INPUT ARGUMENTS:
      A:               Atmosphere structure that is to be added to.
                       In the context of the CRTM, rank-1 corresponds to an
                       vector of profiles, and rank-2 corresponds to an array
                       of channels x profiles. The latter is used in the
                       K-matrix model.
                       UNITS:      N/A
                       TYPE:       CRTM_Atmosphere_type
                       DIMENSION:  Scalar, Rank-1, or Rank-2 array
                       ATTRIBUTES: INTENT(IN OUT)

      B:               Atmosphere structure that is to be weighted and
                       added to structure A.
                       UNITS:      N/A
                       TYPE:       CRTM_Atmosphere_type
                       DIMENSION:  Same as A
                       ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Scale_Factor:    The first weighting factor used to scale the
                       contents of the input structure, B.
                       If not specified, Scale_Factor = 1.0.
                       UNITS:      N/A
                       TYPE:       REAL(fp)
                       DIMENSION:  Scalar
                       ATTRIBUTES: INTENT(IN), OPTIONAL

      Offset:          The second weighting factor used to offset the
                       sum of the input structures.
                       If not specified, Offset = 0.0.
                       UNITS:      N/A
                       TYPE:       REAL(fp)
                       DIMENSION:  Scalar
                       ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:     Character string specifying a filename in which any
                       messages will be logged. If not specified, or if an
                       error occurs opening the log file, the default action
                       is to output messages to standard output.
                       UNITS:      N/A
                       TYPE:       CHARACTER(*)
```

```
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

  OUTPUT ARGUMENTS:
        A:              Structure containing the summation result,
                        A = A + Scale_Factor*B + Offset
                        UNITS:      N/A
                        TYPE:       CRTM_Atmosphere_type
                        DIMENSION:  Same as B
                        ATTRIBUTES: INTENT(IN OUT)

  FUNCTION RESULT:
        Error_Status:   The return value is an integer defining the error status.
                        The error codes are defined in the Message_Handler module.
                        If == SUCCESS the structure assignment was successful
                           == FAILURE an error occurred
                        UNITS:      N/A
                        TYPE:       INTEGER
                        DIMENSION:  Scalar

  SIDE EFFECTS:
        The argument A is INTENT(IN OUT) and is modified upon output.
```

A.2.8 CRTM_Zero_Atmosphere interface

```
  NAME:
        CRTM_Zero_Atmosphere

  PURPOSE:
        Subroutine to zero-out various members of a CRTM Atmosphere structure -
        both scalar and pointer.

  CALLING SEQUENCE:
        CALL CRTM_Zero_Atmosphere( Atmosphere )

  OUTPUT ARGUMENTS:
        Atmosphere:   Zeroed out Atmosphere structure.
                      In the context of the CRTM, rank-1 corresponds to an
                      vector of profiles, and rank-2 corresponds to an array
                      of channels x profiles. The latter is used in the
                      K-matrix model.
                      UNITS:      N/A
                      TYPE:       CRTM_Atmosphere_type
                      DIMENSION:  Scalar, Rank-1, or Rank-2 array
                      ATTRIBUTES: INTENT(IN OUT)

  COMMENTS:
        - No checking of the input structure is performed, so there are no
          tests for component association status. This means the Atmosphere
          structure must have allocated components upon entry to this
```

```
    routine.

  - The dimension components of the structure are *NOT* set to zero.

  - The Absorber_ID and Absorber_Units components are *NOT* zeroed out
    in this routine.

  - Note the INTENT on the output Atmosphere argument is IN OUT rather than
    just OUT. This is necessary because the argument must be defined upon
    input.
```

A.2.9 CRTM_RCS_ID_Atmosphere interface

```
NAME:
      CRTM_RCS_ID_Atmosphere

PURPOSE:
      Subroutine to return the module RCS Id information.

CALLING SEQUENCE:
      CALL CRTM_RCS_Id_Atmosphere( RCS_Id )

OUTPUT ARGUMENTS:
      RCS_Id:        Character string containing the Revision Control
                     System Id field for the module.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(OUT)
```


A.2.10 CRTM_Inquire_Atmosphere_Binary interface

```
NAME:
      CRTM_Inquire_Atmosphere_Binary

PURPOSE:
      Function to inquire Binary format CRTM Atmosphere structure files.

CALLING SEQUENCE:
      Error_Status = CRTM_Inquire_Atmosphere_Binary( Filename               , &
                                                     n_Channels =n_Channels , &
                                                     n_Profiles =n_Profiles , &
                                                     RCS_Id     =RCS_Id     , &
                                                     Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an
```

```
                    Atmosphere format data file to read.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

  OPTIONAL INPUT ARGUMENTS:
        Message_Log:  Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to standard output.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

  OPTIONAL OUTPUT ARGUMENTS:
        n_Channels:   The number of spectral channels for which there is
                      data in the file. Note that this value will always
                      be 0 for a profile-only dataset-- it only has meaning
                      for K-matrix data.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(OUT)

        n_Profiles:   The number of profiles in the data file.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(OUT)

        RCS_Id:       Character string containing the version control Id
                      field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(OUT)

  FUNCTION RESULT:
        Error_Status: The return value is an integer defining the error status.
                      The error codes are defined in the Message_Handler module.
                      If == SUCCESS the Binary file inquire was successful
                         == FAILURE an unrecoverable error occurred.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
```

A.2.11 CRTM_Read_Atmosphere_Binary interface

```
NAME:
      CRTM_Read_Atmosphere_Binary

PURPOSE:
      Function to read Binary format CRTM Atmosphere structure files.

CALLING SEQUENCE:
      Error_Status = CRTM_Read_Atmosphere_Binary( Filename               , &
                                                  Atmosphere             , &
                                                  Quiet      =Quiet      , &
                                                  n_Channels =n_Channels , &
                                                  n_Profiles =n_Profiles , &
                                                  RCS_Id     =RCS_Id     , &
                                                  Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an
                    Atmosphere format data file to read.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Atmosphere:   Structure containing the Atmosphere data. Note the
                    following meanings attributed to the dimensions of
                    the structure array:
                    Rank-1: M profiles.
                            Only profile data are to be read in. The file
                            does not contain channel information. The
                            dimension of the structure is understood to
                            be the PROFILE dimension.
                    Rank-2: L channels  x  M profiles
                            Channel and profile data are to be read in.
                            The file contains both channel and profile
                            information. The first dimension of the
                            structure is the CHANNEL dimension, the second
                            is the PROFILE dimension. This is to allow
                            K-matrix structures to be read in with the
                            same function.
                    UNITS:      N/A
                    TYPE:       CRTM_Atmosphere_type
                    DIMENSION:  Rank-1 (M) or Rank-2 (L x M)
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Quiet:        Set this argument to suppress INFORMATION messages
                    being printed to standard output (or the message
                    log file if the Message_Log optional argument is
                    used.) By default, INFORMATION messages are printed.
                    If QUIET = 0, INFORMATION messages are OUTPUT.
                       QUIET = 1, INFORMATION messages are SUPPRESSED.
                    UNITS:      N/A
                    TYPE:       INTEGER
```

```
                  DIMENSION:  Scalar
                  ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      n_Channels:   The number of channels for which data was read. Note that
                    this value will always be 0 for a profile-only dataset--
                    it only has meaning for K-matrix data.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

      n_Profiles:   The number of profiles for which data was read.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:       Character string containing the version control Id
                    field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the Binary file read was successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Atmosphere argument is IN OUT rather
      than just OUT. This is necessary because the argument may be defined on
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```


A.2.12 CRTM_Write_Atmosphere_Binary interface

```
NAME:
      CRTM_Write_Atmosphere_Binary

PURPOSE:
      Function to write Binary format Atmosphere files.

CALLING SEQUENCE:
      Error_Status = CRTM_Write_Atmosphere_Binary( Filename               , &
                                                   Atmosphere             , &
                                                   Quiet      =Quiet      , &
                                                   RCS_Id     =RCS_Id     , &
                                                   Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an output
                    Atmosphere format data file.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

      Atmosphere:   Structure containing the Atmosphere data to write.
                    Note the following meanings attributed to the
                    dimensions of the structure array:
                    Rank-1: M profiles.
                            Only profile data are to be read in. The file
                            does not contain channel information. The
                            dimension of the structure is understood to
                            be the PROFILE dimension.
                    Rank-2: L channels  x  M profiles
                            Channel and profile data are to be read in.
                            The file contains both channel and profile
                            information. The first dimension of the
                            structure is the CHANNEL dimension, the second
                            is the PROFILE dimension. This is to allow
                            K-matrix structures to be read in with the
                            same function.
                    UNITS:      N/A
                    TYPE:       CRTM_Atmosphere_type
                    DIMENSION:  Rank-1 (M) or Rank-2 (L x M)
                    ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Quiet:        Set this argument to suppress INFORMATION messages
                    being printed to standard output (or the message
                    log file if the Message_Log optional argument is
                    used.) By default, INFORMATION messages are printed.
                    If QUIET = 0, INFORMATION messages are OUTPUT.
                       QUIET = 1, INFORMATION messages are SUPPRESSED.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL
```

```
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      RCS_Id:       Character string containing the version control Id
                    field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the Binary file write was successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

SIDE EFFECTS:
      - If the output file already exists, it is overwritten.
      - If an error occurs *during* the write phase, the output file is deleted
        before returning to the calling routine.
```

A.3 `Cloud` Structure

```
TYPE :: CRTM_Cloud_type
  INTEGER :: n_Allocates = 0
  ! Dimension values
  INTEGER :: Max_Layers = 0  ! K dimension.
  INTEGER :: n_Layers   = 0  ! Kuse dimension.
  ! Number of added layers
  INTEGER :: n_Added_Layers = 0
  ! Cloud type
  INTEGER :: Type = NO_CLOUD
  ! Cloud state variables
  REAL(fp), POINTER :: Effective_Radius(:)   => NULL() ! K. Units are microns
  REAL(fp), POINTER :: Effective_Variance(:) => NULL() ! K. Units are microns^2
  REAL(fp), POINTER :: Water_Content(:) => NULL()      ! K. Units are kg/m^2
END TYPE CRTM_Cloud_type
```

Figure A.3: CRTM_Cloud_type structure definition.

Cloud Type	Parameter
Water	WATER_CLOUD
Ice	ICE_CLOUD
Rain	RAIN_CLOUD
Snow	SNOW_CLOUD
Graupel	GRAUPEL_CLOUD
Hail	HAIL_CLOUD

Table A.4: CRTM `Cloud` structure valid `Type` definitions.

A.3.1 CRTM_Associated_Cloud interface

```
NAME:
      CRTM_Associated_Cloud

PURPOSE:
      Function to test the association status of a CRTM Cloud structure.

CALLING SEQUENCE:
      Association_Status = CRTM_Associated_Cloud( Cloud            , &
                                                  ANY_Test=Any_Test  )

INPUT ARGUMENTS:
      Cloud:               Cloud structure which is to have its pointer
                           member's association status tested.
                           UNITS:      N/A
                           TYPE:       CRTM_Cloud_type
                           DIMENSION:  Scalar OR Rank-1 array
                           ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ANY_Test:            Set this argument to test if ANY of the
                           Cloud structure pointer members are associated.
                           The default is to test if ALL the pointer members
                           are associated.
                           If ANY_Test = 0, test if ALL the pointer members
                                            are associated.  (DEFAULT)
                              ANY_Test = 1, test if ANY of the pointer members
                                            are associated.
                           UNITS:      N/A
                           TYPE:       INTEGER
                           DIMENSION:  Scalar
                           ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Association_Status:  The return value is a logical value indicating the
                           association status of the Cloud pointer members.
                           .TRUE.  - if ALL the Cloud pointer members are
                                     associated, or if the ANY_Test argument
                                     is set and ANY of the Cloud pointer
                                     members are associated.
                           .FALSE. - some or all of the Cloud pointer
                                     members are NOT associated.
                           UNITS:      N/A
                           TYPE:       LOGICAL
                           DIMENSION:  Same as input Cloud argument
```

A.3.2 CRTM_Allocate_Cloud interface

```
NAME:
```

```
      CRTM_Allocate_Cloud

PURPOSE:
      Function to allocate CRTM Cloud structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Allocate_Cloud( n_Layers               , &
                                          Cloud                  , &
                                          Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Layers:     Number of layers for which there is cloud data.
                    Must be > 0.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar OR Rank-1 array
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Cloud:        Cloud structure with allocated pointer members.
                    UNITS:      N/A
                    TYPE:       CRTM_Cloud_type
                    DIMENSION:  Same as input n_Layers argument
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to one (1) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Cloud argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.3.3 *CRTM_Destroy_Cloud interface*

```
NAME:
      CRTM_Destroy_Cloud

PURPOSE:
      Function to re-initialize CRTM Cloud structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy_Cloud( Cloud                  , &
                                         Message_Log=Message_Log  )

OUTPUT ARGUMENTS:
      Cloud:        Re-initialized Cloud structure.
                    UNITS:      N/A
                    TYPE:       CRTM_Cloud_type
                    DIMENSION:  Scalar OR Rank-1 array
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to zero (0) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Cloud argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.3.4 *CRTM_Assign_Cloud interface*

```
NAME:
      CRTM_Assign_Cloud

PURPOSE:
      Function to copy valid CRTM Cloud structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Assign_Cloud( Cloud_in               , &
                                        Cloud_out              , &
                                        Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Cloud_in:      Cloud structure which is to be copied.
                     UNITS:      N/A
                     TYPE:       CRTM_Cloud_type
                     DIMENSION:  Scalar or Rank-1 array
                     ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Cloud_out:     Copy of the input structure, Cloud_in.
                     UNITS:      N/A
                     TYPE:       CRTM_Cloud_type
                     DIMENSION:  Same as Cloud_in argument
                     ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:   Character string specifying a filename in which any
                     messages will be logged. If not specified, or if an
                     error occurs opening the log file, the default action
                     is to output messages to standard output.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:  The return value is an integer defining the error status.
                     The error codes are defined in the Message_Handler module.
                     If == SUCCESS the structure assignment was successful
                        == FAILURE an error occurred
                     UNITS:      N/A
                     TYPE:       INTEGER
                     DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Cloud argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.3.5 CRTM_Equal_Cloud interface

```
NAME:
      CRTM_Equal_Cloud

PURPOSE:
      Function to test if two Cloud structures are equal.

CALLING SEQUENCE:
      Error_Status = CRTM_Equal_Cloud( Cloud_LHS              , &
                                       Cloud_RHS              , &
                                       ULP_Scale  =ULP_Scale  , &
                                       Check_All  =Check_All  , &
                                       Message_Log=Message_Log  )


INPUT ARGUMENTS:
      Cloud_LHS:          Cloud structure to be compared; equivalent to the
                          left-hand side of a lexical comparison, e.g.
                            IF ( Cloud_LHS == Cloud_RHS ).
                          UNITS:      N/A
                          TYPE:       CRTM_Cloud_type
                          DIMENSION:  Scalar OR Rank-1 array
                          ATTRIBUTES: INTENT(IN)

      Cloud_RHS:          Cloud structure to be compared to; equivalent to
                          right-hand side of a lexical comparison, e.g.
                            IF ( Cloud_LHS == Cloud_RHS ).
                          UNITS:      N/A
                          TYPE:       CRTM_Cloud_type
                          DIMENSION:  Same as Cloud_RHS argument
                          ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ULP_Scale:          Unit of data precision used to scale the floating
                          point comparison. ULP stands for "Unit in the Last Place,"
                          the smallest possible increment or decrement that can be
                          made using a machine's floating point arithmetic.
                          Value must be positive - if a negative value is supplied,
                          the absolute value is used. If not specified, the default
                          value is 1.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

      Check_All:          Set this argument to check ALL the floating point
                          channel data of the Cloud structures. The default
                          action is return with a FAILURE status as soon as
                          any difference is found. This optional argument can
                          be used to get a listing of ALL the differences
                          between data in Cloud structures.
                          If == 0, Return with FAILURE status as soon as
```

```
                              ANY difference is found  *DEFAULT*
                           == 1, Set FAILURE status if ANY difference is
                              found, but continue to check ALL data.
                         UNITS:      N/A
                         TYPE:       INTEGER
                         DIMENSION:  Scalar
                         ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:       Character string specifying a filename in which any
                         messages will be logged. If not specified, or if an
                         error occurs opening the log file, the default action
                         is to output messages to standard output.
                         UNITS:      None
                         TYPE:       CHARACTER(*)
                         DIMENSION:  Scalar
                         ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:      The return value is an integer defining the error status.
                         The error codes are defined in the Message_Handler module.
                         If == SUCCESS the structures were equal
                            == FAILURE - an error occurred, or
                                       - the structures were different.
                         UNITS:      N/A
                         TYPE:       INTEGER
                         DIMENSION:  Scalar
```

A.3.6 CRTM_SetLayers_Cloud interface

```
NAME:
      CRTM_SetLayers_Cloud

PURPOSE:
      Function to set the number of layers to use in a CRTM Cloud
      structure.

CALLING SEQUENCE:
      Error_Status = CRTM_SetLayers_Cloud( n_Layers               , &
                                           Cloud                  , &
                                           Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Layers:     The value to set the n_Layers component of the
                    Cloud structure, as well as those of any of its
                    structure components.
                    UNITS:      N/A
                    TYPE:       CRTM_Cloud_type
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)
```

```
      Cloud:        Cloud structure in which the n_Layers dimension
                    is to be updated.
                    UNITS:      N/A
                    TYPE:       CRTM_Cloud_type
                    DIMENSION:  Scalar OR Rank-1 array
                    ATTRIBUTES: INTENT(IN OUT)
OUTPUT ARGUMENTS:
      Cloud:        On output, the Cloud structure with the updated
                    n_Layers dimension.
                    UNITS:      N/A
                    TYPE:       CRTM_Cloud_type
                    DIMENSION:  Scalar or Rank-1 array
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      None
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the layer reset was successful
                       == FAILURE an error occurred
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

SIDE EFFECTS:
      The argument Cloud is INTENT(IN OUT) and is modified upon output. The
      elements of the structure are reinitialised

COMMENTS:
      - Note that the n_Layers input is *ALWAYS* scalar. Thus, all Cloud
        elements will be set to the same number of layers.

      - If n_Layers <= Cloud%Max_Layers, then only the dimension value
        of the structure and any sub-structures are changed.

      - If n_Layers > Cloud%Max_Layers, then the entire structure is
        reallocated to the required number of layers.
```

A.3.7 CRTM_Sum_Cloud interface

```
NAME:
```

```
      CRTM_Sum_Cloud

PURPOSE:
      Function to perform a sum of two valid CRTM Cloud structures. The
      summation performed is:
        A = A + Scale_Factor*B + Offset
      where A and B are the CRTM Cloud structures, and Scale_Factor and Offset
      are optional weighting factors.

CALLING SEQUENCE:
      Error_Status = CRTM_Sum_Cloud( A                         , &
                                     B                         , &
                                     Scale_Factor=Scale_Factor, &
                                     Offset      =Offset      , &
                                     Message_Log =Message_Log   )

INPUT ARGUMENTS:
      A:             Cloud structure that is to be added to.
                     UNITS:      N/A
                     TYPE:       CRTM_Cloud_type
                     DIMENSION:  Scalar OR Rank-1 array
                     ATTRIBUTES: INTENT(IN OUT)

      B:             Cloud structure that is to be weighted and
                     added to structure A.
                     UNITS:      N/A
                     TYPE:       CRTM_Cloud_type
                     DIMENSION:  Same as A
                     ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      A:             Structure containing the summation result,
                       A = A + Scale_Factor*B + Offset
                     UNITS:      N/A
                     TYPE:       CRTM_Cloud_type
                     DIMENSION:  Same as B
                     ATTRIBUTES: INTENT(IN OUT)


OPTIONAL INPUT ARGUMENTS:
      Scale_Factor:  The first weighting factor used to scale the
                     contents of the input structure, B.
                     If not specified, Scale_Factor = 1.0.
                     UNITS:      N/A
                     TYPE:       REAL(fp)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(IN), OPTIONAL

      Offset:        The second weighting factor used to offset the
                     sum of the input structures.
                     If not specified, Offset = 0.0.
                     UNITS:      N/A
                     TYPE:       REAL(fp)
                     DIMENSION:  Scalar
```

```
                    ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure summation was successful
                       == FAILURE an error occurred
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

SIDE EFFECTS:
      The argument A is INTENT(IN OUT) and is modified upon output.
```

A.3.8 CRTM_Zero_Cloud interface

```
NAME:
      CRTM_Zero_Cloud

PURPOSE:
      Subroutine to zero-out various members of a CRTM Cloud structure - both
      scalar and pointer.

CALLING SEQUENCE:
      CALL CRTM_Zero_Cloud( Cloud )

OUTPUT ARGUMENTS:
      Cloud:        Zeroed out Cloud structure.
                    UNITS:      N/A
                    TYPE:       CRTM_Cloud_type
                    DIMENSION:  Scalar or Rank-1 array
                    ATTRIBUTES: INTENT(IN OUT)

COMMENTS:
      - No checking of the input structure is performed, so there are no
        tests for pointer member association status. This means the Cloud
        structure must have allocated pointer members upon entry to this
        routine.

      - The dimension components of the structure are *NOT* set to zero.
```

```
      - The cloud type component is *NOT* reset.

      - Note the INTENT on the output Cloud argument is IN OUT rather than
        just OUT. This is necessary because the argument must be defined upon
        input.
```

A.3.9 CRTM_RCS_ID_Cloud interface

```
NAME:
      CRTM_RCS_ID_Cloud

PURPOSE:
      Subroutine to return the module RCS Id information.

CALLING SEQUENCE:
      CALL CRTM_RCS_Id_Cloud( RCS_Id )

OUTPUT ARGUMENTS:
      RCS_Id:        Character string containing the Revision Control
                     System Id field for the module.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(OUT)
```

A.3.10 CRTM_Inquire_Cloud_Binary interface

```
NAME:
      CRTM_Inquire_Cloud_Binary

PURPOSE:
      Function to inquire Binary format CRTM Cloud structure files.

CALLING SEQUENCE:
      Error_Status = CRTM_Inquire_Cloud_Binary( Filename              , &
                                                n_Clouds   =n_Clouds  , &
                                                RCS_Id     =RCS_Id    , &
                                                Message_Log=Message_Log )

INPUT ARGUMENTS:
      Filename:       Character string specifying the name of a
                      Cloud format data file to read.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN)
```

```
OPTIONAL INPUT ARGUMENTS:
      Message_Log:    Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to standard output.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      n_Clouds:       The number of Cloud profiles in the data file.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status:   The return value is an integer defining the error status.
                      The error codes are defined in the ERROR_HANDLER module.
                      If == SUCCESS the Binary file inquire was successful
                         == FAILURE an unrecoverable error occurred.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
```


A.3.11 CRTM_Read_Cloud_Binary interface

```
NAME:
      CRTM_Read_Cloud_Binary

PURPOSE:
      Function to read Binary format CRTM Cloud structure files.

CALLING SEQUENCE:
      Error_Status = CRTM_Read_Cloud_Binary( Filename                  , &
                                             Cloud                     , &
                                             Quiet        =Quiet       , &
                                             No_File_Close=No_File_Close, &
                                             No_Allocate  =No_Allocate  , &
                                             n_Clouds     =n_Clouds     , &
                                             RCS_Id       =RCS_Id       , &
                                             Message_Log  =Message_Log    )
```

```
INPUT ARGUMENTS:
      Filename:       Character string specifying the name of a
                      Cloud format data file to read.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Cloud:          Structure containing the Cloud data.
                      UNITS:      N/A
                      TYPE:       CRTM_Cloud_type
                      DIMENSION:  Rank-1
                      ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Quiet:          Set this argument to suppress INFORMATION messages
                      being printed to standard output (or the message
                      log file if the Message_Log optional argument is
                      used.)
                      If == 0, INFORMATION messages are OUTPUT [DEFAULT].
                         == 1, INFORMATION messages are SUPPRESSED.
                      If not specified, information messages are output.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

      No_File_Close:  Set this argument to NOT close the file upon exit.
                      If == 0, the input file is closed upon exit [DEFAULT]
                         == 1, the input file is NOT closed upon exit.
                      If not specified, the default action is to close the
                      input file upon exit.
                      the
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(IN)

      No_Allocate:    Set this argument to NOT allocate the output Cloud
                      structure in this routine based on the data dimensions
                      read from the input data file. This assumes that the
                      structure has already been allocated prior to calling
                      this function.
                      If == 0, the output Cloud structure is allocated [DEFAULT]
                         == 1, the output Cloud structure is NOT allocated
                      If not specified, the default action is to allocate
                      the output Cloud structure to the dimensions specified
                      in the input data file.
                      the
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
```

```
                    ATTRIBUTES: OPTIONAL, INTENT(IN)

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL


OPTIONAL OUTPUT ARGUMENTS:
      n_Clouds:     The actual number of cloud profiles read in.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:       Character string containing the Revision Control
                    System Id field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the ERROR_HANDLER module.
                    If == SUCCESS the Binary file read was successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

SIDE EFFECTS:
      If an error occurs:
      - the input file is closed and,
      - the output Cloud structure is deallocated.

COMMENTS:
      Note the INTENT on the output Cloud argument is IN OUT rather
      than just OUT. This is necessary because the argument may be defined on
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.3.12 CRTM_Write_Cloud_Binary interface

```
NAME:
      CRTM_Write_Cloud_Binary
```

```
PURPOSE:
      Function to write Binary format Cloud files.

CALLING SEQUENCE:
      Error_Status = CRTM_Write_Cloud_Binary( Filename                  , &
                                              Cloud                     , &
                                              Quiet        =Quiet       , &
                                              No_File_Close=No_File_Close, &
                                              RCS_Id       =RCS_Id      , &
                                              Message_Log  =Message_Log   )

INPUT ARGUMENTS:
      Filename:       Character string specifying the name of an output
                      Cloud format data file.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN)

      Cloud:          Structure containing the Cloud data.
                      UNITS:      N/A
                      TYPE:       CRTM_Cloud_type
                      DIMENSION:  Rank-1
                      ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Quiet:          Set this argument to suppress INFORMATION messages
                      being printed to standard output (or the message
                      log file if the Message_Log optional argument is
                      used.)
                      If == 0, INFORMATION messages are OUTPUT [DEFAULT].
                         == 1, INFORMATION messages are SUPPRESSED.
                      If not specified, information messages are output.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

      No_File_Close:  Set this argument to NOT close the file upon exit.
                      If == 0, the input file is closed upon exit [DEFAULT]
                         == 1, the input file is NOT closed upon exit.
                      If not specified, the default action is to close the
                      input file upon exit.
                      the
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(IN)

      Message_Log:    Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to standard output.
                      UNITS:      N/A
```

```
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      RCS_Id:       Character string containing the Revision Control
                    System Id field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the ERROR_HANDLER module.
                    If == SUCCESS the Binary file write was successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

SIDE EFFECTS:
      - If the output file already exists, it is overwritten.
      - If an error occurs during *writing*, the output file is deleted before
        returning to the calling routine.
```

A.4 `Aerosol` Structure

```
TYPE :: CRTM_Aerosol_type
  INTEGER :: n_Allocates = 0
  ! Dimensions
  INTEGER :: Max_Layers = 0  ! K dimension.
  INTEGER :: n_Layers   = 0  ! K dimension
  ! Number of added layers
  INTEGER :: n_Added_Layers = 0
  ! Aerosol type
  INTEGER :: Type = NO_AEROSOL
  ! Aerosol state variables
  REAL(fp), POINTER :: Effective_Radius(:) => NULL()  ! K. Units are microns
  REAL(fp), POINTER :: Concentration(:)    => NULL()  ! K. Units are kg/m^2
END TYPE CRTM_Aerosol_type
```

Figure A.4: CRTM_Aerosol_type structure definition.

Aerosol Type	Parameter
Dust	DUST_AEROSOL
Sea salt SSAM[1]	SEASALT_SSAM_AEROSOL
Sea salt SSCM[2]	SEASALT_SSCM_AEROSOL
Dry organic carbon	DRY_ORGANIC_CARBON_AEROSOL
Wet organic carbon	WET_ORGANIC_CARBON_AEROSOL
Dry black carbon	DRY_BLACK_CARBON_AEROSOL
Wet black carbon	WET_BLACK_CARBON_AEROSOL
Sulfate	SULFATE_AEROSOL

Table A.5: CRTM `Aerosol` structure valid `Type` definitions.

A.4.1 *CRTM_Associated_Aerosol interface*

```
NAME:
      CRTM_Associated_Aerosol

PURPOSE:
      Function to test the association status of the pointer members of a
      CRTM Aerosol structure.

CALLING SEQUENCE:
      Association_Status = CRTM_Associated_Aerosol( Aerosol          , &
                                                    ANY_Test=Any_Test  )

INPUT ARGUMENTS:
      Aerosol:             Aerosol structure which is to have its pointer
                           member's association status tested.
                           UNITS:      N/A
                           TYPE:       CRTM_Aerosol_type
                           DIMENSION:  Scalar OR Rank-1 array
                           ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ANY_Test:            Set this argument to test if ANY of the
                           Aerosol structure pointer members are associated.
                           The default is to test if ALL the pointer members
                           are associated.
                           If ANY_Test = 0, test if ALL the pointer members
                                            are associated.  (DEFAULT)
                              ANY_Test = 1, test if ANY of the pointer members
                                            are associated.
                           UNITS:      N/A
                           TYPE:       INTEGER
                           DIMENSION:  Scalar
                           ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Association_Status:  The return value is a logical value indicating the
                           association status of the Aerosol pointer members.
                           .TRUE.  - if ALL the Aerosol pointer members are
                                     associated, or if the ANY_Test argument
                                     is set and ANY of the Aerosol pointer
                                     members are associated.
                           .FALSE. - some or all of the Aerosol pointer
                                     members are NOT associated.
                           UNITS:      N/A
                           TYPE:       LOGICAL
                           DIMENSION:  Same as input Aerosol argument
```

A.4.2 *CRTM_Allocate_Aerosol interface*

```
NAME:
      CRTM_Allocate_Aerosol

PURPOSE:
      Function to allocate the pointer members of the CRTM Aerosol
      data structure.

CALLING SEQUENCE:
      Error_Status = CRTM_Allocate_Aerosol( n_Layers               , &
                                            Aerosol                , &
                                            Message_Log=Message_Log  )

INPUT ARGUMENTS:
        n_Layers:   Number of atmospheric layers dimension.
                    Must be > 0
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar OR Rank-1 array
                    ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OUTPUT ARGUMENTS:
      Aerosol:      Aerosol structure with allocated pointer members.
                    UNITS:      N/A
                    TYPE:       CRTM_Aerosol_type
                    DIMENSION:  Same as input n_Layers argument
                    ATTRIBUTES: INTENT(IN OUT)


FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to one (1) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Aerosol argument is IN OUT rather than
```

```
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.4.3 CRTM_Destroy_Aerosol interface

```
NAME:
      CRTM_Destroy_Aerosol

PURPOSE:
      Function to re-initialize the scalar and pointer members of
      a CRTM Aerosol data structure.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy_Aerosol( Aerosol                , &
                                           Message_Log=Message_Log  )

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OUTPUT ARGUMENTS:
      Aerosol:      Re-initialized Aerosol structure.
                    UNITS:      N/A
                    TYPE:       CRTM_Aerosol_type
                    DIMENSION:  Scalar OR Rank-1 array
                    ATTRIBUTES: INTENT(IN OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to zero (0) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Aerosol argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
```

```
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.4.4 CRTM_Assign_Aerosol interface

```
  NAME:
        CRTM_Assign_Aerosol

  PURPOSE:
        Function to copy valid CRTM Aerosol structures.

  CALLING SEQUENCE:
        Error_Status = CRTM_Assign_Aerosol( Aerosol_in             , &
                                            Aerosol_out            , &
                                            Message_Log=Message_Log  )

  INPUT ARGUMENTS:
        Aerosol_in:       Aerosol structure which is to be copied.
                          UNITS:      N/A
                          TYPE:       CRTM_Aerosol_type
                          DIMENSION:  Scalar OR Rank-1 array
                          ATTRIBUTES: INTENT(IN)

  OUTPUT ARGUMENTS:
        Aerosol_out:      Copy of the input structure, Aerosol_in.
                          UNITS:      N/A
                          TYPE:       CRTM_Aerosol_type
                          DIMENSION:  Same as Aerosol_in argument
                          ATTRIBUTES: INTENT(IN OUT)


  OPTIONAL INPUT ARGUMENTS:
        Message_Log:      Character string specifying a filename in which any
                          messages will be logged. If not specified, or if an
                          error occurs opening the log file, the default action
                          is to output messages to standard output.
                          UNITS:      N/A
                          TYPE:       CHARACTER(*)
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

  FUNCTION RESULT:
        Error_Status:     The return value is an integer defining the error status.
                          The error codes are defined in the Message_Handler module.
                          If == SUCCESS the structure assignment was successful
                             == FAILURE an error occurred
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar

  COMMENTS:
```

```
      Note the INTENT on the output Aerosol argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.4.5 CRTM_Equal_Aerosol interface

```
NAME:
      CRTM_Equal_Aerosol

PURPOSE:
      Function to test if two Aerosol structures are equal.

CALLING SEQUENCE:
      Error_Status = CRTM_Equal_Aerosol( Aerosol_LHS            , &
                                         Aerosol_RHS            , &
                                         ULP_Scale  =ULP_Scale  , &
                                         Check_All  =Check_All  , &
                                         Message_Log=Message_Log  )


INPUT ARGUMENTS:
      Aerosol_LHS:       Aerosol structure to be compared; equivalent to the
                         left-hand side of a lexical comparison, e.g.
                           IF ( Aerosol_LHS == Aerosol_RHS ).
                         UNITS:      N/A
                         TYPE:       CRTM_Aerosol_type
                         DIMENSION:  Scalar OR Rank-1 array
                         ATTRIBUTES: INTENT(IN)

      Aerosol_RHS:       Aerosol structure to be compared to; equivalent to
                         right-hand side of a lexical comparison, e.g.
                           IF ( Aerosol_LHS == Aerosol_RHS ).
                         UNITS:      N/A
                         TYPE:       CRTM_Aerosol_type
                         DIMENSION:  Same as Aerosol_LHS
                         ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ULP_Scale:         Unit of data precision used to scale the floating
                         point comparison. ULP stands for "Unit in the Last Place,"
                         the smallest possible increment or decrement that can be
                         made using a machine's floating point arithmetic.
                         Value must be positive - if a negative value is supplied,
                         the absolute value is used. If not specified, the default
                         value is 1.
                         UNITS:      N/A
                         TYPE:       INTEGER
                         DIMENSION:  Scalar
                         ATTRIBUTES: INTENT(IN), OPTIONAL
```

```
      Check_All:          Set this argument to check ALL the floating point
                          channel data of the Aerosol structures. The default
                          action is return with a FAILURE status as soon as
                          any difference is found. This optional argument can
                          be used to get a listing of ALL the differences
                          between data in Aerosol structures.
                          If == 0, Return with FAILURE status as soon as
                                   ANY difference is found  *DEFAULT*
                             == 1, Set FAILURE status if ANY difference is
                                   found, but continue to check ALL data.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:        Character string specifying a filename in which any
                          messages will be logged. If not specified, or if an
                          error occurs opening the log file, the default action
                          is to output messages to standard output.
                          UNITS:      None
                          TYPE:       CHARACTER(*)
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:       The return value is an integer defining the error status.
                          The error codes are defined in the Message_Handler module.
                          If == SUCCESS the structures were equal
                             == FAILURE - an error occurred, or
                                        - the structures were different.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
```


A.4.6 CRTM_SetLayers_Aerosol interface

```
NAME:
      CRTM_SetLayers_Aerosol

PURPOSE:
      Function to set the number of layers to use in a CRTM Aerosol
      structure.

CALLING SEQUENCE:
      Error_Status = CRTM_SetLayers_Aerosol( n_Layers              , &
                                             Aerosol               , &
                                             Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Layers:     The value to set the n_Layers component of the
```

```
                  Aerosol structure, as well as those of any of its
                  structure components.
                  UNITS:      N/A
                  TYPE:       CRTM_Aerosol_type
                  DIMENSION:  Scalar
                  ATTRIBUTES: INTENT(IN)

      Aerosol:    Aerosol structure in which the n_Layers dimension
                  is to be updated.
                  UNITS:      N/A
                  TYPE:       CRTM_Aerosol_type
                  DIMENSION:  Scalar or Rank-1 array
                  ATTRIBUTES: INTENT(IN OUT)
OUTPUT ARGUMENTS:
      Aerosol:    On output, the Aerosol structure with the updated
                  n_Layers dimension.
                  UNITS:      N/A
                  TYPE:       CRTM_Aerosol_type
                  DIMENSION:  Scalar or Rank-1 array
                  ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                  messages will be logged. If not specified, or if an
                  error occurs opening the log file, the default action
                  is to output messages to standard output.
                  UNITS:      None
                  TYPE:       CHARACTER(*)
                  DIMENSION:  Scalar
                  ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                  The error codes are defined in the Message_Handler module.
                  If == SUCCESS the layer reset was successful
                     == FAILURE an error occurred
                  UNITS:      N/A
                  TYPE:       INTEGER
                  DIMENSION:  Scalar

SIDE EFFECTS:
      The argument Aerosol is INTENT(IN OUT) and is modified upon output. The
      elements of the structureare reinitialised

COMMENTS:
      - Note that the n_Layers input is *ALWAYS* scalar. Thus, all Aerosol
        elements will be set to the same number of layers.

      - If n_Layers <= Aerosol%Max_Layers, then only the dimension value
        of the structure and any sub-structures are changed.

      - If n_Layers > Aerosol%Max_Layers, then the entire structure is
        reallocated to the required number of layers.
```

A.4.7 *CRTM_Sum_Aerosol interface*

```
NAME:
      CRTM_Sum_Aerosol

PURPOSE:
      Function to perform a sum of two valid CRTM Aerosol structures. The
      summation performed is:
        A = A + Scale_Factor*B + Offset
      where A and B are the CRTM Aerosol structures, and Scale_Factor and Offset
      are optional weighting factors.

CALLING SEQUENCE:
      Error_Status = CRTM_Sum_Aerosol( A                         , &
                                       B                         , &
                                       Scale_Factor=Scale_Factor, &
                                       Offset      =Offset       , &
                                       Message_Log =Message_Log    )

INPUT ARGUMENTS:
      A:             Aerosol structure that is to be added to.
                     UNITS:      N/A
                     TYPE:       CRTM_Aerosol_type
                     DIMENSION:  Scalar OR Rank-1
                     ATTRIBUTES: INTENT(IN OUT)

      B:             Aerosol structure that is to be weighted and
                     added to structure A.
                     UNITS:      N/A
                     TYPE:       CRTM_Aerosol_type
                     DIMENSION:  Same as A
                     ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Scale_Factor:  The first weighting factor used to scale the
                     contents of the input structure, B.
                     If not specified, Scale_Factor = 1.0.
                     UNITS:      N/A
                     TYPE:       REAL(fp)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(IN), OPTIONAL

      Offset:        The second weighting factor used to offset the
                     sum of the input structures.
                     If not specified, Offset = 0.0.
                     UNITS:      N/A
                     TYPE:       REAL(fp)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(IN), OPTIONAL
```

```
      Message_Log:   Character string specifying a filename in which any
                     messages will be logged. If not specified, or if an
                     error occurs opening the log file, the default action
                     is to output messages to standard output.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(IN), OPTIONAL

OUTPUT ARGUMENTS:
      A:             Structure containing the summation result,
                       A = A + Scale_Factor*B + Offset
                     UNITS:      N/A
                     TYPE:       CRTM_Aerosol_type
                     DIMENSION:  Same as B
                     ATTRIBUTES: INTENT(IN OUT)


FUNCTION RESULT:
      Error_Status:  The return value is an integer defining the error status.
                     The error codes are defined in the Message_Handler module.
                     If == SUCCESS the structure summation was successful
                        == FAILURE an error occurred
                     UNITS:      N/A
                     TYPE:       INTEGER
                     DIMENSION:  Scalar

SIDE EFFECTS:
      The argument A is INTENT(IN OUT) and is modified upon output.
```

A.4.8 *CRTM_Zero_Aerosol interface*

```
NAME:
      CRTM_Zero_Aerosol

PURPOSE:
      Subroutine to zero-out all members of a CRTM Aerosol structure - both
      scalar and pointer.

CALLING SEQUENCE:
      CALL CRTM_Zero_Aerosol( Aerosol )

OUTPUT ARGUMENTS:
      Aerosol: Zeroed out Aerosol structure.
               UNITS:      N/A
               TYPE:       CRTM_Aerosol_type
               DIMENSION:  Scalar or Rank-1 array
               ATTRIBUTES: INTENT(IN OUT)

COMMENTS:
```

```
      - No checking of the input structure is performed, so there are no
        tests for pointer member association status. This means the Aerosol
        structure must have allocated pointer members upon entry to this
        routine.

      - The dimension components of the structure are *NOT*
        set to zero.

      - The aerosol type component is *NOT* reset.

      - Note the INTENT on the output Aerosol argument is IN OUT rather than
        just OUT. This is necessary because the argument must be defined upon
        input.
```

A.4.9 CRTM_RCS_ID_Aerosol interface

```
  NAME:
        CRTM_RCS_ID_Aerosol

  PURPOSE:
        Subroutine to return the module RCS Id information.

  CALLING SEQUENCE:
        CALL CRTM_RCS_Id_Aerosol( RCS_Id )

  OUTPUT ARGUMENTS:
        RCS_Id:         Character string containing the Revision Control
                        System Id field for the module.
                        UNITS:      N/A
                        TYPE:       CHARACTER(*)
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(OUT)
```


A.4.10 CRTM_Inquire_Aerosol_Binary interface

```
  NAME:
        CRTM_Inquire_Aerosol_Binary

  PURPOSE:
        Function to inquire Binary format CRTM Aerosol structure files.

  CALLING SEQUENCE:
        Error_Status = CRTM_Inquire_Aerosol_Binary( Filename              , &
                                                    n_Aerosols =n_Aerosols, &
                                                    RCS_Id     =RCS_Id    , &
                                                    Message_Log=Message_Log )
```

```
INPUT ARGUMENTS:
      Filename:       Character string specifying the name of a
                      Aerosol format data file to read.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:    Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to standard output.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      n_Aerosols:     The number of Aerosol profiles in the data file.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status:   The return value is an integer defining the error status.
                      The error codes are defined in the ERROR_HANDLER module.
                      If == SUCCESS the Binary file inquire was successful
                         == FAILURE an unrecoverable error occurred.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
```


A.4.11 CRTM_Read_Aerosol_Binary interface

```
NAME:
      CRTM_Read_Aerosol_Binary

PURPOSE:
      Function to read Binary format CRTM Aerosol structure files.

CALLING SEQUENCE:
```

```
      Error_Status = CRTM_Read_Aerosol_Binary( Filename                  , &
                                               Aerosol                   , &
                                               Quiet        =Quiet       , &
                                               No_File_Close=No_File_Close, &
                                               No_Allocate  =No_Allocate  , &
                                               n_Aerosols   =n_Aerosols   , &
                                               RCS_Id       =RCS_Id       , &
                                               Message_Log  =Message_Log    )

INPUT ARGUMENTS:
      Filename:       Character string specifying the name of a
                      Aerosol format data file to read.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Aerosol:        Structure containing the Aerosol data.
                      UNITS:      N/A
                      TYPE:       CRTM_Aerosol_type
                      DIMENSION:  Rank-1
                      ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Quiet:          Set this argument to suppress INFORMATION messages
                      being printed to standard output (or the message
                      log file if the Message_Log optional argument is
                      used.)
                      If == 0, INFORMATION messages are OUTPUT [DEFAULT].
                         == 1, INFORMATION messages are SUPPRESSED.
                      If not specified, information messages are output.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

      No_File_Close:  Set this argument to NOT close the file upon exit.
                      If == 0, the input file is closed upon exit [DEFAULT]
                         == 1, the input file is NOT closed upon exit.
                      If not specified, the default action is to close the
                      input file upon exit.
                      the
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(IN)

      No_Allocate:    Set this argument to NOT allocate the output Aerosol
                      structure in this routine based on the data dimensions
                      read from the input data file. This assumes that the
                      structure has already been allocated prior to calling
                      this function.
                      If == 0, the output Aerosol structure is allocated [DEFAULT]
```

```
                        == 1, the output Aerosol structure is NOT allocated
                     If not specified, the default action is to allocate
                     the output Aerosol structure to the dimensions specified
                     in the input data file.
                     the
                     UNITS:      N/A
                     TYPE:       INTEGER
                     DIMENSION:  Scalar
                     ATTRIBUTES: OPTIONAL, INTENT(IN)

      Message_Log:   Character string specifying a filename in which any
                     messages will be logged. If not specified, or if an
                     error occurs opening the log file, the default action
                     is to output messages to standard output.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(IN), OPTIONAL


OPTIONAL OUTPUT ARGUMENTS:
      n_Aerosols:    The actual number of aerosol profiles read in.
                     UNITS:      N/A
                     TYPE:       INTEGER
                     DIMENSION:  Scalar
                     ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:        Character string containing the Revision Control
                     System Id field for the module.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status:  The return value is an integer defining the error status.
                     The error codes are defined in the ERROR_HANDLER module.
                     If == SUCCESS the Binary file read was successful
                        == FAILURE an unrecoverable error occurred.
                     UNITS:      N/A
                     TYPE:       INTEGER
                     DIMENSION:  Scalar

SIDE EFFECTS:
      If an error occurs:
      - the input file is closed and,
      - the output Aerosol structure is deallocated.

COMMENTS:
      Note the INTENT on the output Aerosol argument is IN OUT rather
      than just OUT. This is necessary because the argument may be defined on
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.4.12 *CRTM_Write_Aerosol_Binary interface*

```
NAME:
      CRTM_Write_Aerosol_Binary

PURPOSE:
      Function to write Binary format Aerosol files.

CALLING SEQUENCE:
      Error_Status = CRTM_Write_Aerosol_Binary( Filename                  , &
                                                Aerosol                   , &
                                                Quiet        =Quiet       , &
                                                No_File_Close=No_File_Close, &
                                                RCS_Id       =RCS_Id      , &
                                                Message_Log  =Message_Log   )

INPUT ARGUMENTS:
      Filename:       Character string specifying the name of an output
                      Aerosol format data file.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN)

      Aerosol:        Structure containing the Aerosol data.
                      UNITS:      N/A
                      TYPE:       CRTM_Aerosol_type
                      DIMENSION:  Rank-1
                      ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Quiet:          Set this argument to suppress INFORMATION messages
                      being printed to standard output (or the message
                      log file if the Message_Log optional argument is
                      used.)
                      If == 0, INFORMATION messages are OUTPUT [DEFAULT].
                         == 1, INFORMATION messages are SUPPRESSED.
                      If not specified, information messages are output.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

      No_File_Close:  Set this argument to NOT close the file upon exit.
                      If == 0, the input file is closed upon exit [DEFAULT]
                         == 1, the input file is NOT closed upon exit.
                      If not specified, the default action is to close the
                      input file upon exit.
                      the
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(IN)
```

```
      Message_Log:    Character string specifying a filename in which any
                      messages will be logged. If not specified, or if an
                      error occurs opening the log file, the default action
                      is to output messages to standard output.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status:   The return value is an integer defining the error status.
                      The error codes are defined in the ERROR_HANDLER module.
                      If == SUCCESS the Binary file write was successful
                         == FAILURE an unrecoverable error occurred.
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar

SIDE EFFECTS:
      - If the output file already exists, it is overwritten.
      - If an error occurs during *writing*, the output file is deleted before
        returning to the calling routine.
```

A.5 `Surface` Structure

```
TYPE :: CRTM_Surface_type
  INTEGER :: n_Allocates = 0
  ! Dimension values
  INTEGER :: Max_Sensors  = 0  ! N dimension
  INTEGER :: n_Sensors    = 0  ! Nuse dimension
  ! Gross type of surface determined by coverage
  REAL(fp) :: Land_Coverage  = ZERO
  REAL(fp) :: Water_Coverage = ZERO
  REAL(fp) :: Snow_Coverage  = ZERO
  REAL(fp) :: Ice_Coverage   = ZERO
  ! Surface type independent data
  REAL(fp) :: Wind_Speed     = DEFAULT_WIND_SPEED
  REAL(fp) :: Wind_Direction = DEFAULT_WIND_DIRECTION
  ! Land surface type data
  INTEGER  :: Land_Type             = DEFAULT_LAND_TYPE
  REAL(fp) :: Land_Temperature      = DEFAULT_LAND_TEMPERATURE
  REAL(fp) :: Soil_Moisture_Content = DEFAULT_SOIL_MOISTURE_CONTENT
  REAL(fp) :: Canopy_Water_Content  = DEFAULT_CANOPY_WATER_CONTENT
  REAL(fp) :: Vegetation_Fraction   = DEFAULT_VEGETATION_FRACTION
  REAL(fp) :: Soil_Temperature      = DEFAULT_SOIL_TEMPERATURE
  ! Water type data
  INTEGER  :: Water_Type        = DEFAULT_WATER_TYPE
  REAL(fp) :: Water_Temperature = DEFAULT_WATER_TEMPERATURE
  REAL(fp) :: Salinity          = DEFAULT_SALINITY
  ! Snow surface type data
  INTEGER  :: Snow_Type        = DEFAULT_SNOW_TYPE
  REAL(fp) :: Snow_Temperature = DEFAULT_SNOW_TEMPERATURE
  REAL(fp) :: Snow_Depth       = DEFAULT_SNOW_DEPTH
  REAL(fp) :: Snow_Density     = DEFAULT_SNOW_DENSITY
  REAL(fp) :: Snow_Grain_Size  = DEFAULT_SNOW_GRAIN_SIZE
  ! Ice surface type data
  INTEGER  :: Ice_Type        = DEFAULT_ICE_TYPE
  REAL(fp) :: Ice_Temperature = DEFAULT_ICE_TEMPERATURE
  REAL(fp) :: Ice_Thickness   = DEFAULT_ICE_THICKNESS
  REAL(fp) :: Ice_Density     = DEFAULT_ICE_DENSITY
  REAL(fp) :: Ice_Roughness   = DEFAULT_ICE_ROUGHNESS
  ! SensorData containing channel brightness temperatures
  TYPE(CRTM_SensorData_type) :: SensorData  ! N
END TYPE CRTM_Surface_type
```

Figure A.5: CRTM_Surface_type structure definition.

Component	Description	Units	Dimensions
n_Sensors	The number of sensors for which data is provided inside the SensorData structure	N/A	Scalar
Land_Coverage	Fraction of the FOV that is land surface	N/A	Scalar
Water_Coverage	Fraction of the FOV that is water surface	N/A	Scalar
Snow_Coverage	Fraction of the FOV that is snow surface	N/A	Scalar
Ice_Coverage	Fraction of the FOV that is ice surface	N/A	Scalar
Wind_Speed	Surface wind speed	$m.s^{-1}$	Scalar
Wind_Direction	Surface wind direction	deg. E from N	Scalar
Land_Type	Land surface type	N/A	Scalar
Land_Temperature	Land surface temperature	Kelvin	Scalar
Soil_Moisture_Content	Volumetric water content of the soil	$g.cm^{-3}$	Scalar
Canopy_Water_Content	Gravimetric water content of the canopy	$g.cm^{-3}$	Scalar
Vegetation_Fraction	Vegetation fraction of the surface	%	Scalar
Soil_Temperature	Soil temperature	Kelvin	Scalar
Water_Type	Water surface type	N/A	Scalar
Water_Temperature	Water surface temperature	Kelvin	Scalar
Salinity	Water salinity	‰	Scalar
Snow_Type	Snow surface type	N/A	Scalar
Snow_Temperature	Snow surface temperature	Kelvin	Scalar
Snow_Depth	Snow depth	mm	Scalar
Snow_Density	Snow density	$g.m^{-3}$	Scalar
Snow_Grain_Size	Snow grain size	mm	Scalar
Ice_Type	Ice surface type	N/A	Scalar
Ice_Temperature	Ice surface temperature	Kelvin	Scalar
Ice_Thickness	Thickness of ice	mm	Scalar
Ice_Density	Density of ice	$g.m^{-3}$	Scalar
Ice_Roughness	Measure of the surface roughness of the ice	N/A	Scalar
SensorData	Satellite sensor data required for some surface emissivity algorithms	N/A	Scalar

Table A.6: CRTM Surface structure component description.

Parameter	Value	Units
Surface type independent data		
DEFAULT_WIND_SPEED	5.0	$m.s^{-1}$
DEFAULT_WIND_DIRECTION	0.0	deg. E from N
Land surface type data		
DEFAULT_LAND_TYPE	GRASS_SOIL	N/A
DEFAULT_LAND_TEMPERATURE	283.0	K
DEFAULT_SOIL_MOISTURE_CONTENT	0.05	$g.cm^{-3}$
DEFAULT_CANOPY_WATER_CONTENT	0.05	$g.cm^{-3}$
DEFAULT_VEGETATION_FRACTION	0.3	30%
DEFAULT_SOIL_TEMPERATURE	283.0	K
Water type data		
DEFAULT_WATER_TYPE	SEA_WATER	N/A
DEFAULT_WATER_TEMPERATURE	283.0	K
DEFAULT_SALINITY	33.0	ppmv
Snow surface type data		
DEFAULT_SNOW_TYPE	NEW_SNOW	N/A
DEFAULT_SNOW_TEMPERATURE	263.0	K
DEFAULT_SNOW_DEPTH	50.0	mm
DEFAULT_SNOW_DENSITY	0.2	$g.cm^{-3}$
DEFAULT_SNOW_GRAIN_SIZE	2.0	mm
Ice surface type data		
DEFAULT_ICE_TYPE	FRESH_ICE	N/A
DEFAULT_ICE_TEMPERATURE	263.0	K
DEFAULT_ICE_THICKNESS	10.0	mm
DEFAULT_ICE_DENSITY	0.9	$g.cm^{-3}$
DEFAULT_ICE_ROUGHNESS	0.0	N/A

Table A.7: CRTM `Surface` structure default values.

Land Type	Parameter
Compacted soil	COMPACTED_SOIL
Tilled soil	TILLED_SOIL
Sand	SAND
Rock	ROCK
Irrigated low vegetation	IRRIGATED_LOW_VEGETATION
Meadow grass	MEADOW_GRASS
Scrub	SCRUB
Broadleaf forest	BROADLEAF_FOREST
Pine forest	PINE_FOREST
Tundra	TUNDRA
Grass-soil	GRASS_SOIL
Broadleaf-pine forest	BROADLEAF_PINE_FOREST
Grass scrub	GRASS_SCRUB
Soil-grass-scrub	SOIL_GRASS_SCRUB
Urban concrete	URBAN_CONCRETE
Pine brush	PINE_BRUSH
Broadleaf brush	BROADLEAF_BRUSH
Wet soil	WET_SOIL
Scrub-soil	SCRUB_SOIL
Broadleaf(70)-Pine(30)	BROADLEAF70_PINE30

Table A.8: CRTM Surface structure valid Land_Type definitions.

Water Type	Parameter
Sea water	SEA_WATER
Fresh water	FRESH_WATER

Table A.9: CRTM Surface structure valid Water_Type definitions.

Snow Type	Parameter
Wet snow	WET_SNOW
Grass after snow	GRASS_AFTER_SNOW
Powder snow	POWDER_SNOW
RS snow(A)	RS_SNOW_A
RS snow(B)	RS_SNOW_B
RS snow(C)	RS_SNOW_C
RS snow(D)	RS_SNOW_D
RS snow(E)	RS_SNOW_E
Thin Crust snow	THIN_CRUST_SNOW
Thick crust snow	THICK_CRUST_SNOW
Shallow snow	SHALLOW_SNOW
Deep snow	DEEP_SNOW
Crust snow	CRUST_SNOW
Medium snow	MEDIUM_SNOW
Bottom crust snow(A)	BOTTOM_CRUST_SNOW_A
Bottom crust snow(B)	BOTTOM_CRUST_SNOW_B

Table A.10: CRTM Surface structure valid Snow_Type definitions.

Ice Type	Parameter
Fresh ice	FRESH_ICE
First year sea ice	FIRST_YEAR_SEA_ICE
Multiple year sea ice	MULTI_YEAR_SEA_ICE
Ice floe	ICE_FLOE
Ice ridge	ICE_RIDGE

Table A.11: CRTM Surface structure valid Ice_Type definitions.

A.5.1 CRTM_Allocate_Surface interface

```
NAME:
      CRTM_Allocate_Surface

PURPOSE:
      Function to allocate CRTM Surface data structures.

      NOTE: This function is a wrapper for the CRTM_SensorData allocation
            routine to provide the functionality and convenience for
            allocation of both scalar and rank-1 Surface structures in
            the same manner as for CRTM_Atmosphere_type structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Allocate_Surface( n_Channels             , &
                                            Surface                , &
                                            Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Channels:   Number of channels dimension of Surface%SensorData
                    structure
                    ** Note: Can be = 0 (i.e. no sensor data). **
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar OR Rank-1
                                See output Surface dimensionality table
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Surface:      Surface structure with allocated SensorData pointer
                    members. The following table shows the allowable dimension
                    combinations for the calling routine, where M == number of
                    profiles/surface locations:

                       Input       Output
                     n_Channels    Surface
                      dimension    dimension
                    --------------------------
                       scalar       scalar
                       scalar         M
                         M            M

                    These multiple interfaces are supplied purely for ease of
                    use depending on what data is available.

                    UNITS:      N/A
                    TYPE:       CRTM_Surface_type
                    DIMENSION:  Scalar or Rank-1
                                See chart above.
                    ATTRIBUTES: INTENT(IN OUT)


OPTIONAL INPUT ARGUMENTS:
```

```
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to one (1) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Surface argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.5.2 CRTM_Destroy_Surface interface

```
NAME:
      CRTM_Destroy_Surface

PURPOSE:
      Function to re-initialize the scalar and pointer members of Surface
      data structures.

      NOTE: This function is mostly a wrapper for the CRTM_SensorData
            destruction routine to provide the functionality and convenience
            of allocation of both scalar and rank-1 Surface structures in
            the same manner as for CRTM_Atmosphere_type structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy_Surface( Surface                , &
                                           Message_Log=Message_Log  )

OUTPUT ARGUMENTS:
      Surface:      Re-initialized Surface structure. In the context of
                    the CRTM, rank-1 corresponds to an vector of profiles,
                    and rank-2 corresponds to an array of channels x profiles.
```

```
                    The latter is used in the K-matrix model.
                    UNITS:      N/A
                    TYPE:       CRTM_Surface_type
                    DIMENSION:  Scalar, Rank-1, OR Rank-2 array
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to zero (0) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Surface argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```


A.5.3 CRTM_Assign_Surface interface

```
NAME:
      CRTM_Assign_Surface

PURPOSE:
      Function to copy valid Surface structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Assign_Surface( Surface_in             , &
                                          Surface_out            , &
                                          Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Surface_in:   Surface structure which is to be copied. In the context of
```

```
                  the CRTM, rank-1 corresponds to an vector of profiles,
                  and rank-2 corresponds to an array of channels x profiles.
                  The latter is used in the K-matrix model.
                  UNITS:      N/A
                  TYPE:       CRTM_Surface_type
                  DIMENSION:  Scalar, Rank-1, OR Rank-2 array
                  ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Surface_out:  Copy of the input structure, Surface_in.
                  UNITS:      N/A
                  TYPE:       CRTM_Surface_type
                  DIMENSION:  Same as Surface_in
                  ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                  messages will be logged. If not specified, or if an
                  error occurs opening the log file, the default action
                  is to output messages to standard output.
                  UNITS:      N/A
                  TYPE:       CHARACTER(*)
                  DIMENSION:  Scalar
                  ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                  The error codes are defined in the Message_Handler module.
                  If == SUCCESS the structure assignment was successful
                     == FAILURE an error occurred
                  UNITS:      N/A
                  TYPE:       INTEGER
                  DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Surface argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```


A.5.4 CRTM_Equal_Surface interface

```
NAME:
      CRTM_Equal_Surface

PURPOSE:
      Function to test if two Surface structures are equal.

CALLING SEQUENCE:
      Error_Status = CRTM_Equal_Surface( Surface_LHS                          , &
                                         Surface_RHS                          , &
```

```
                                  ULP_Scale         =ULP_Scale         , &
                                  Percent_Difference=Percent_Difference, &
                                  Check_All         =Check_All         , &
                                  Message_Log       =Message_Log         )


INPUT ARGUMENTS:
      Surface_LHS:        Surface structure to be compared; equivalent to the
                          left-hand side of a lexical comparison, e.g.
                            IF ( Surface_LHS == Surface_RHS ).
                          UNITS:      N/A
                          TYPE:       CRTM_Surface_type
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN)

      Surface_RHS:        Surface structure to be compared to; equivalent to
                          right-hand side of a lexical comparison, e.g.
                            IF ( Surface_LHS == Surface_RHS ).
                          UNITS:      N/A
                          TYPE:       CRTM_Surface_type
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ULP_Scale:          Unit of data precision used to scale the floating
                          point comparison. ULP stands for "Unit in the Last Place,"
                          the smallest possible increment or decrement that can be
                          made using a machine's floating point arithmetic.
                          Value must be positive - if a negative value is supplied,
                          the absolute value is used. If not specified, the default
                          value is 1.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

      Percent_Differnece: Percentage difference value to use in comparing
                          the numbers rather than testing within some numerical
                          limit. The ULP_Scale argument is ignored if this argument is
                          specified.
                          UNITS:      N/A
                          TYPE:       REAL(fp)
                          DIMENSION:  Scalar
                          ATTRIBUTES: OPTIONAL, INTENT(IN)

      Check_All:          Set this argument to check ALL the floating point
                          channel data of the Surface structures. The default
                          action is return with a FAILURE status as soon as
                          any difference is found. This optional argument can
                          be used to get a listing of ALL the differences
                          between data in Surface structures.
                          If == 0, Return with FAILURE status as soon as
                                   ANY difference is found  *DEFAULT*
                             == 1, Set FAILURE status if ANY difference is
```

```
                          found, but continue to check ALL data.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      None
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structures were equal
                       == FAILURE - an error occurred, or
                                  - the structures were different.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
```

A.5.5 CRTM_Sum_Surface interface

```
NAME:
      CRTM_Sum_Surface

PURPOSE:
      Function to perform a sum of two valid CRTM Surface structures. The
      summation performed is:
        A = A + Scale_Factor*B + Offset
      where A and B are the CRTM Surface structures, and Scale_Factor and
      Offset are optional weighting factors.

CALLING SEQUENCE:
      Error_Status = CRTM_Sum_Surface( A                         , &
                                       B                         , &
                                       Scale_Factor=Scale_Factor, &
                                       Offset      =Offset      , &
                                       Message_Log =Message_Log   )

INPUT ARGUMENTS:
      A:               Surface structure that is to be added to.
                       In the context of the CRTM, rank-1 corresponds to an
                       vector of profiles, and rank-2 corresponds to an array
                       of channels x profiles. The latter is used in the
                       K-matrix model.
```

```
                        UNITS:      N/A
                        TYPE:       CRTM_Surface_type
                        DIMENSION:  Scalar, Rank-1, or Rank-2 array
                        ATTRIBUTES: INTENT(IN OUT)

      B:                Surface structure that is to be weighted and
                        added to structure A.
                        UNITS:      N/A
                        TYPE:       CRTM_Surface_type
                        DIMENSION:  Same as A
                        ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      A:                Structure containing the weight sum result,
                          A = A + Scale_Factor*B + Offset
                        UNITS:      N/A
                        TYPE:       CRTM_Surface_type
                        DIMENSION:  Same as B
                        ATTRIBUTES: INTENT(IN OUT)


OPTIONAL INPUT ARGUMENTS:
      Scale_Factor:     The first weighting factor used to scale the
                        contents of the input structure, B.
                        If not specified, Scale_Factor = 1.0.
                        UNITS:      N/A
                        TYPE:       REAL(fp)
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

      Offset:           The second weighting factor used to offset the
                        sum of the input structures.
                        If not specified, Offset = 0.0.
                        UNITS:      N/A
                        TYPE:       REAL(fp)
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:      Character string specifying a filename in which any
                        messages will be logged. If not specified, or if an
                        error occurs opening the log file, the default action
                        is to output messages to standard output.
                        UNITS:      N/A
                        TYPE:       CHARACTER(*)
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:     The return value is an integer defining the error status.
                        The error codes are defined in the Message_Handler module.
                        If == SUCCESS the structure assignment was successful
                           == FAILURE an error occurred
                        UNITS:      N/A
                        TYPE:       INTEGER
```

```
                        DIMENSION:  Scalar

SIDE EFFECTS:
      The argument A is INTENT(IN OUT) and is modified upon output.

COMMENTS:
      The SensorData component of the Surface structures are not operated on.
```

A.5.6 *CRTM_Zero_Surface interface*

```
NAME:
      CRTM_Zero_Surface

PURPOSE:
      Subroutine to zero-out members of a CRTM Surface structure.

CALLING SEQUENCE:
      CALL CRTM_Zero_Surface( Surface )

OUTPUT ARGUMENTS:
      Surface:      Zeroed out Surface structure.
                    In the context of the CRTM, rank-1 corresponds to an
                    vector of profiles, and rank-2 corresponds to an array
                    of channels x profiles. The latter is used in the
                    K-matrix model.
                    UNITS:      N/A
                    TYPE:       CRTM_Surface_type
                    DIMENSION:  Scalar, Rank-1, or Rank-2 array
                    ATTRIBUTES: INTENT(IN OUT)

COMMENTS:
      - No checking of the input structure is performed.

      - The SensorData dimension and structure components are *NOT*
        reset.

      - Note the INTENT on the output Surface argument is IN OUT rather than
        just OUT. This is necessary because the argument must be defined upon
        input.
```

A.5.7 *CRTM_RCS_ID_Surface interface*

```
NAME:
      CRTM_RCS_ID_Surface

PURPOSE:
      Subroutine to return the module RCS Id information.
```

```
CALLING SEQUENCE:
      CALL CRTM_RCS_Id_Surface( RCS_Id )

OUTPUT ARGUMENTS:
      RCS_Id:        Character string containing the Revision Control
                     System Id field for the module.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(OUT)
```

A.5.8 CRTM_Inquire_Surface_Binary interface

```
NAME:
      CRTM_Inquire_Surface_Binary

PURPOSE:
      Function to inquire Binary format CRTM Surface structure files.

CALLING SEQUENCE:
      Error_Status = CRTM_Inquire_Surface_Binary( Filename               , &
                                                  n_Channels =n_Channels , &
                                                  n_Profiles =n_Profiles , &
                                                  RCS_Id     =RCS_Id     , &
                                                  Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an
                    Surface format data file to read.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      n_Channels:   The number of spectral channels for which there is
                    data in the file. Note that this value will always
                    be 0 for a profile-only dataset-- it only has meaning
                    for K-matrix data.
```

```
                  UNITS:      N/A
                  TYPE:       INTEGER
                  DIMENSION:  Scalar
                  ATTRIBUTES: OPTIONAL, INTENT(OUT)

      n_Profiles: The number of profiles in the data file.
                  UNITS:      N/A
                  TYPE:       INTEGER
                  DIMENSION:  Scalar
                  ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:     Character string containing the version control Id
                  field for the module.
                  UNITS:      N/A
                  TYPE:       CHARACTER(*)
                  DIMENSION:  Scalar
                  ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the Binary inquiry was successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
```

A.5.9 CRTM_Read_Surface_Binary interface

```
NAME:
      CRTM_Read_Surface_Binary

PURPOSE:
      Function to read Binary format CRTM Surface structure files.

CALLING SEQUENCE:
      Error_Status = CRTM_Read_Surface_Binary( Filename               , &
                                               Surface                , &
                                               Quiet      =Quiet      , &
                                               n_Channels =n_Channels , &
                                               n_Profiles =n_Profiles , &
                                               RCS_Id     =RCS_Id     , &
                                               Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an
                    Surface format data file to read.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
```

```
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Surface:      Structure containing the Surface data. Note the
                    following meanings attributed to the dimensions of
                    the structure array:
                    Rank-1: M profiles.
                            Only profile data are to be read in. The file
                            does not contain channel information. The
                            dimension of the structure is understood to
                            be the PROFILE dimension.
                    Rank-2: L channels  x  M profiles
                            Channel and profile data are to be read in.
                            The file contains both channel and profile
                            information. The first dimension of the
                            structure is the CHANNEL dimension, the second
                            is the PROFILE dimension. This is to allow
                            K-matrix structures to be read in with the
                            same function.
                    UNITS:      N/A
                    TYPE:       CRTM_Surface_type
                    DIMENSION:  Rank-1 (M) or Rank-2 (L x M)
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Quiet:        Set this argument to suppress INFORMATION messages
                    being printed to standard output (or the message
                    log file if the Message_Log optional argument is
                    used.) By default, INFORMATION messages are printed.
                    If QUIET = 0, INFORMATION messages are OUTPUT.
                       QUIET = 1, INFORMATION messages are SUPPRESSED.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      n_Channels:   The number of channels for which data was read. Note that
                    this value will always be 0 for a profile-only dataset--
                    it only has meaning for K-matrix data.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)
```

```
      n_Profiles:   The number of profiles for which data was read.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:       Character string containing the version control Id
                    field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the Binary file read was successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Surface argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.5.10 CRTM_Write_Surface_Binary interface

```
NAME:
      CRTM_Write_Surface_Binary

PURPOSE:
      Function to write Binary format Surface files.

CALLING SEQUENCE:
      Error_Status = CRTM_Write_Surface_Binary( Filename               , &
                                                Surface                , &
                                                Quiet      =Quiet      , &
                                                RCS_Id     =RCS_Id     , &
                                                Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an output
                    Surface format data file.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)
```

```
      Surface:      Structure containing the Surface data to write.
                    Note the following meanings attributed to the
                    dimensions of the structure array:
                    Rank-1: M profiles.
                            Only profile data are to be read in. The file
                            does not contain channel information. The
                            dimension of the structure is understood to
                            be the PROFILE dimension.
                    Rank-2: L channels  x  M profiles
                            Channel and profile data are to be read in.
                            The file contains both channel and profile
                            information. The first dimension of the
                            structure is the CHANNEL dimension, the second
                            is the PROFILE dimension. This is to allow
                            K-matrix structures to be read in with the
                            same function.
                    UNITS:      N/A
                    TYPE:       CRTM_Surface_type
                    DIMENSION:  Rank-1 (M) or Rank-2 (L x M)
                    ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Quiet:        Set this argument to suppress INFORMATION messages
                    being printed to standard output (or the message
                    log file if the Message_Log optional argument is
                    used.) By default, INFORMATION messages are printed.
                    If QUIET = 0, INFORMATION messages are OUTPUT.
                       QUIET = 1, INFORMATION messages are SUPPRESSED.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      RCS_Id:       Character string containing the version control Id
                    field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the Binary file write was successful
```

```
                    == FAILURE an unrecoverable error occurred.
                UNITS:      N/A
                TYPE:       INTEGER
                DIMENSION:  Scalar

SIDE EFFECTS:
      - If the output file already exists, it is overwritten.
      - If an error occurs *during* the write phase, the output file is deleted
        before returning to the calling routine.
```

A.5.11 SensorData Structure

```
TYPE :: CRTM_SensorData_type
  INTEGER :: n_Allocates = 0
  ! Dimension values
  INTEGER :: n_Channels = 0  ! L
  ! The WMO sensor ID of the sensor for which the data is to be used
  INTEGER :: Select_WMO_Sensor_Id = INVALID_WMO_SENSOR_ID
  ! The data sensor IDs and channels
  CHARACTER(STRLEN), POINTER :: Sensor_Id(:)        => NULL() ! L
  INTEGER,           POINTER :: WMO_Satellite_ID(:) => NULL() ! L
  INTEGER,           POINTER :: WMO_Sensor_ID(:)    => NULL() ! L
  INTEGER,           POINTER :: Sensor_Channel(:)   => NULL() ! L
  ! The sensor brightness temperatures
  REAL(fp),          POINTER :: Tb(:) => NULL() ! L
END TYPE CRTM_SensorData_type
```

Figure A.6: CRTM_SensorData_type structure definition.

Component	Description	Units	Dimensions
n_Channels	Number of channels to use in SfcOptics emissivty algorithms (L)	N/A	Scalar
Select_WMO_Sensor_Id	The WMO Sensor Id value of the sensor for which the data is to be used.	N/A	Scalar
Sensor_Id	The sensor id character string for each channel of data	N/A	L
WMO_Satellite_Id	The WMO satellite Id for each channel of data	N/A	L
WMO_Sensor_Id	The WMO sensor Id for each channel of data	N/A	L
Sensor_Channel	The channel number for each channel of data	N/A	L
Tb	The brightness temperature measurements for each channel	Kelvin	L

Table A.12: CRTM SensorData structure component description.

A.5.12 *CRTM_Associated_SensorData interface*

```
NAME:
      CRTM_Associated_SensorData

PURPOSE:
      Function to test the association status of the pointer members of a
      CRTM_SensorData structure.

CALLING SEQUENCE:
      Association_Status = CRTM_Associated_SensorData( SensorData       , &
                                                       ANY_Test=Any_Test  )

INPUT ARGUMENTS:
      SensorData:  SensorData structure which is to have its pointer
                   member's association status tested.
                   UNITS:      N/A
                   TYPE:       CRTM_SensorData_type
                   DIMENSION:  Scalar
                   ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ANY_Test:    Set this argument to test if ANY of the
                   SensorData structure pointer members are associated.
                   The default is to test if ALL the pointer members
                   are associated.
                   If ANY_Test = 0, test if ALL the pointer members
                                    are associated.  (DEFAULT)
                      ANY_Test = 1, test if ANY of the pointer members
                                    are associated.

FUNCTION RESULT:
      Association_Status:  The return value is a logical value indicating the
                           association status of the SensorData pointer
                           members.
                           .TRUE.  - if ALL the SensorData pointer members
                                     are associated, or if the ANY_Test argument
                                     is set and ANY of the SensorData
                                     pointer members are associated.
                           .FALSE. - some or all of the SensorData pointer
                                     members are NOT associated.
                           UNITS:      N/A
                           TYPE:       LOGICAL
                           DIMENSION:  Scalar
```

A.5.13 *CRTM_Allocate_SensorData interface*

```
NAME:
      CRTM_Allocate_SensorData
```

```
PURPOSE:
      Function to allocate the pointer members of a CRTM SensorData
      data structure.

CALLING SEQUENCE:
      Error_Status = CRTM_Allocate_SensorData( n_Channels             , &
                                               SensorData             , &
                                               Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Channels:   The number of channels in the SensorData structure.
                    Must be > 0.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      SensorData:   SensorData structure with allocated pointer members
                    UNITS:      N/A
                    TYPE:       CRTM_SensorData_type
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN OUT)


OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    Messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output Messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the ERROR_HANDLER module.
                    If == SUCCESS the structure pointer allocations were
                                  successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to one (1) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output SensorData argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.5.14 *CRTM_Destroy_SensorData interface*

```
NAME:
      CRTM_Destroy_SensorData

PURPOSE:
      Function to re-initialize the scalar and pointer members of SensorData
      data structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy_SensorData( SensorData             , &
                                              Message_Log=Message_Log  )

OUTPUT ARGUMENTS:
      SensorData:   Re-initialized SensorData structure.
                    UNITS:      N/A
                    TYPE:       CRTM_SensorData_type
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the ERROR_HANDLER module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to zero (0) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output SensorData argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.5.15 *CRTM_Assign_SensorData interface*

```
NAME:
      CRTM_Assign_SensorData

PURPOSE:
      Function to copy valid SensorData structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Assign_SensorData( SensorData_in          , &
                                             SensorData_out         , &
                                             Message_Log=Message_Log  )

INPUT ARGUMENTS:
      SensorData_in:   SensorData structure which is to be copied.
                       UNITS:      N/A
                       TYPE:       CRTM_SensorData_type
                       DIMENSION:  Scalar OR Rank-1
                       ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      SensorData_out:  Copy of the input structure, SensorData_in.
                       UNITS:      N/A
                       TYPE:       CRTM_SensorData_type
                       DIMENSION:  Same as SensorData_in
                       ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:     Character string specifying a filename in which any
                       messages will be logged. If not specified, or if an
                       error occurs opening the log file, the default action
                       is to output messages to standard output.
                       UNITS:      N/A
                       TYPE:       CHARACTER(*)
                       DIMENSION:  Scalar
                       ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:    The return value is an integer defining the error status.
                       The error codes are defined in the ERROR_HANDLER module.
                       If == SUCCESS the structure assignment was successful
                          == FAILURE an error occurred
                       UNITS:      N/A
                       TYPE:       INTEGER
                       DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output SensorData argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.5.16 CRTM_Equal_SensorData interface

```
NAME:
      CRTM_Equal_SensorData

PURPOSE:
      Function to test if two SensorData structures are equal.

CALLING SEQUENCE:
      Error_Status = CRTM_Equal_SensorData( SensorData_LHS         , &
                                            SensorData_RHS         , &
                                            ULP_Scale  =ULP_Scale  , &
                                            Check_All  =Check_All  , &
                                            Message_Log=Message_Log  )


INPUT ARGUMENTS:
      SensorData_LHS:    SensorData structure to be compared; equivalent to the
                         left-hand side of a lexical comparison, e.g.
                           IF ( SensorData_LHS == SensorData_RHS ).
                         UNITS:      N/A
                         TYPE:       CRTM_SensorData_type
                         DIMENSION:  Scalar
                         ATTRIBUTES: INTENT(IN)

      SensorData_RHS:    SensorData structure to be compared to; equivalent to
                         right-hand side of a lexical comparison, e.g.
                           IF ( SensorData_LHS == SensorData_RHS ).
                         UNITS:      N/A
                         TYPE:       CRTM_SensorData_type
                         DIMENSION:  Scalar
                         ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ULP_Scale:         Unit of data precision used to scale the floating
                         point comparison. ULP stands for "Unit in the Last Place,"
                         the smallest possible increment or decrement that can be
                         made using a machine's floating point arithmetic.
                         Value must be positive - if a negative value is supplied,
                         the absolute value is used. If not specified, the default
                         value is 1.
                         UNITS:      N/A
                         TYPE:       INTEGER
                         DIMENSION:  Scalar
                         ATTRIBUTES: INTENT(IN), OPTIONAL

      Check_All:         Set this argument to check ALL the floating point
                         channel data of the SensorData structures. The default
                         action is return with a FAILURE status as soon as
```

```
                        any difference is found. This optional argument can
                        be used to get a listing of ALL the differences
                        between data in SensorData structures.
                        If == 0, Return with FAILURE status as soon as
                                 ANY difference is found  *DEFAULT*
                           == 1, Set FAILURE status if ANY difference is
                                 found, but continue to check ALL data.
                        UNITS:      N/A
                        TYPE:       INTEGER
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:      Character string specifying a filename in which any
                        messages will be logged. If not specified, or if an
                        error occurs opening the log file, the default action
                        is to output messages to standard output.
                        UNITS:      None
                        TYPE:       CHARACTER(*)
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:     The return value is an integer defining the error status.
                        The error codes are defined in the Message_Handler module.
                        If == SUCCESS the structures were equal
                           == FAILURE - an error occurred, or
                                      - the structures were different.
                        UNITS:      N/A
                        TYPE:       INTEGER
                        DIMENSION:  Scalar
```

A.5.17 CRTM_RCS_ID_SensorData interface

```
NAME:
      CRTM_RCS_ID_SensorData

PURPOSE:
      Subroutine to return the module RCS Id information.

CALLING SEQUENCE:
      CALL CRTM_RCS_Id_SensorData( RCS_Id )

OUTPUT ARGUMENTS:
      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(OUT)
```

A.6 `GeometryInfo` Structure

```
TYPE :: CRTM_GeometryInfo_type
  ! User Input
  ! ----------
  ! Earth location
  REAL(fp) :: Longitude        = ZERO
  REAL(fp) :: Latitude         = ZERO
  REAL(fp) :: Surface_Altitude = ZERO
  ! Field of view index (1-nFOV)
  INTEGER  :: iFOV = 0
  ! Sensor angle information
  REAL(fp) :: Sensor_Scan_Angle    = ZERO
  REAL(fp) :: Sensor_Zenith_Angle  = ZERO
  REAL(fp) :: Sensor_Azimuth_Angle = ZERO
  ! Source angle information
  REAL(fp) :: Source_Zenith_Angle  = 100.0_fp  ! Below horizon
  REAL(fp) :: Source_Azimuth_Angle = ZERO
  ! Flux angle information
  REAL(fp) :: Flux_Zenith_Angle = DIFFUSIVITY_ANGLE
  ! Derived from User Input
  ! -----------------------
  ! Default distance ratio
  REAL(fp) :: Distance_Ratio = EARTH_RADIUS/(EARTH_RADIUS + SATELLITE_HEIGHT)
  ! Sensor angle information
  REAL(fp) :: Sensor_Scan_Radian    = ZERO
  REAL(fp) :: Sensor_Zenith_Radian  = ZERO
  REAL(fp) :: Sensor_Azimuth_Radian = ZERO
  REAL(fp) :: Secant_Sensor_Zenith  = ZERO
  ! Source angle information
  REAL(fp) :: Source_Zenith_Radian  = ZERO
  REAL(fp) :: Source_Azimuth_Radian = ZERO
  REAL(fp) :: Secant_Source_Zenith  = ZERO
  ! Flux angle information
  REAL(fp) :: Flux_Zenith_Radian = DIFFUSIVITY_RADIAN
  REAL(fp) :: Secant_Flux_Zenith = SECANT_DIFFUSIVITY
END TYPE CRTM_GeometryInfo_type
```


Figure A.7: CRTM_GeometryInfo_type structure definition.

Component	Description	Units	Dimensions
Longitude	Earth longitude	deg. E (0→360)	Scalar
Latitude	Earth latitude	deg. N (-90→+90)	Scalar
Surface_Altitude	Altitude of the Earth's surface at the specified lon/lat location	metres (m)	Scalar
iFOV	The scan line FOV index	N/A	Scalar
Sensor_Scan_Angle	The sensor scan angle from nadir. See fig.A.8	degrees	Scalar
Sensor_Zenith_Angle	The sensor zenith angle of the FOV. See fig.A.9	degrees	Scalar
Sensor_Azimuth_Angle	The sensor azimuth angle is the angle subtended by the horizontal projection of a direct line from the satellite to the FOV and the North-South axis measured clockwise from North. See fig.A.10	deg. from N	Scalar
Source_Zenith_Angle	The source zenith angle. The source is typically the Sun (IR/VIS) or Moon (MW/VIS) [only solar source valid in current release] See fig.A.11	degrees	Scalar
Source_Azimuth_Angle	The source azimuth angle is the angle subtended by the horizontal projection of a direct line from the source to the FOV and the North-South axis measured clockwise from North. See fig.A.12	deg. from N	Scalar
Flux_Zenith_Angle	The zenith angle used to approximate downwelling flux transmissivity. If not set, the default value is that of the diffusivity approximation, such that $\sec(F) = 5/3$. Maximum allowed value is determined from $\sec(F) = 9/4$	degrees	Scalar

Table A.13: Description of CRTM GeometryInfo structure components defined by the user.

Component	Description	Units	Dimensions
Distance_Ratio	The ratio of the radius of the earth at the FOV location to the sum of the radius of the earth at nadir, and the satellite altitude; $r = \frac{R_e(FOV)}{R_e(nadir) + h}$. Note that this quantity is actually computed using the user input sensor scan and zenith angles; $r = \frac{\sin(\theta_{scan})}{\sin(\theta_{zenith})}$	N/A	Scalar
Sensor_Scan_Radian	The sensor scan angle in radians	radians	Scalar
Sensor_Zenith_Radian	The sensor scan angle in radians	radians	Scalar
Sensor_Azimuth_Radian	The sensor azimuth angle in radians	radians	Scalar
Secant_Sensor_Zenith	The secant of the sensor zenith angle	N/A	Scalar
Source_Zenith_Radian	The source zenith angle in radians	radians	Scalar
Source_Azimuth_Radian	The source azimuth angle in radians	radians	Scalar
Secant_Source_Zenith	The secant of the source zenith angle	N/A	Scalar
Flux_Zenith_Radian	The flux zenith angle in radians	radians	Scalar
Secant_Flux_Zenith	The secant of the flux zenith angle	N/A	Scalar

Table A.14: Description of CRTM GeometryInfo structure components derived from user inputs.

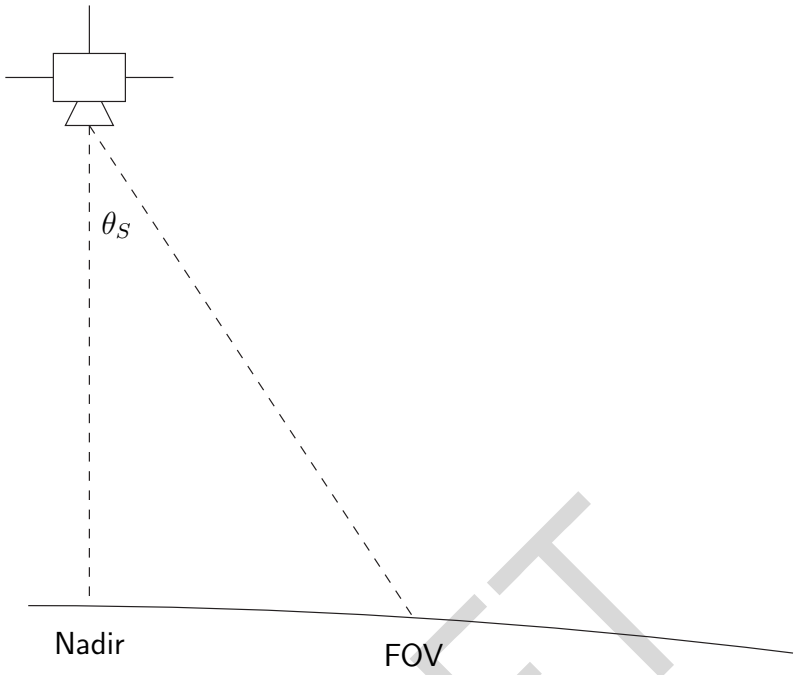


Figure A.8: Definition of `GeometryInfo` sensor scan angle component.

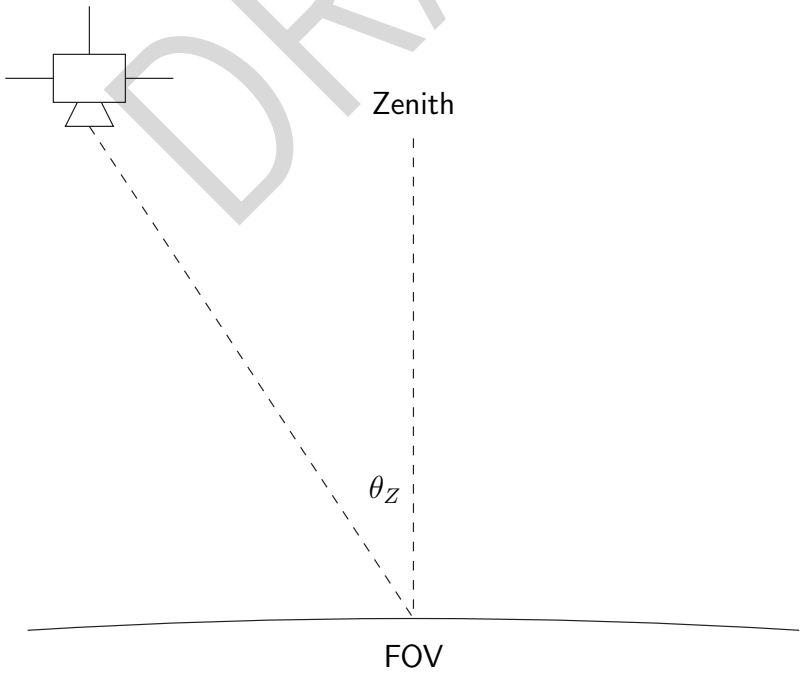


Figure A.9: Definition of `GeometryInfo` sensor zenith angle component.

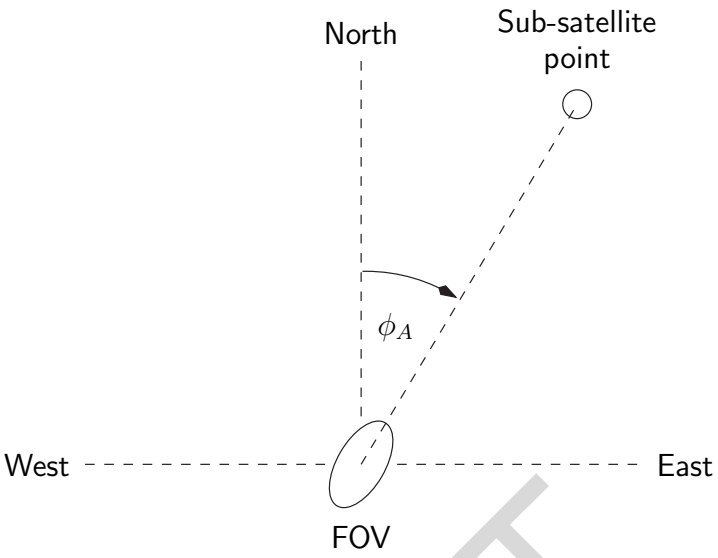


Figure A.10: Definition of `GeometryInfo` sensor azimuth angle component.

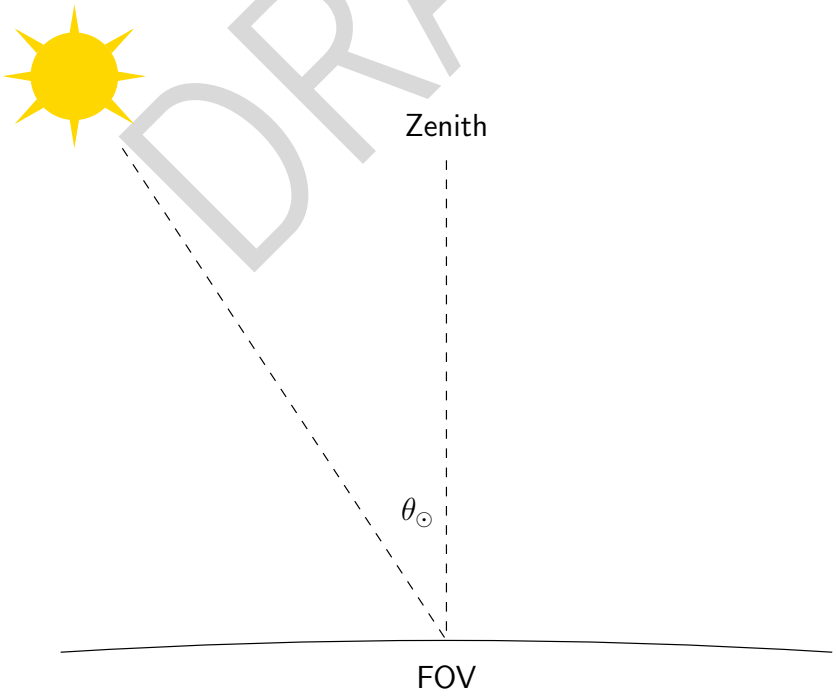


Figure A.11: Definition of `GeometryInfo` source zenith angle component.

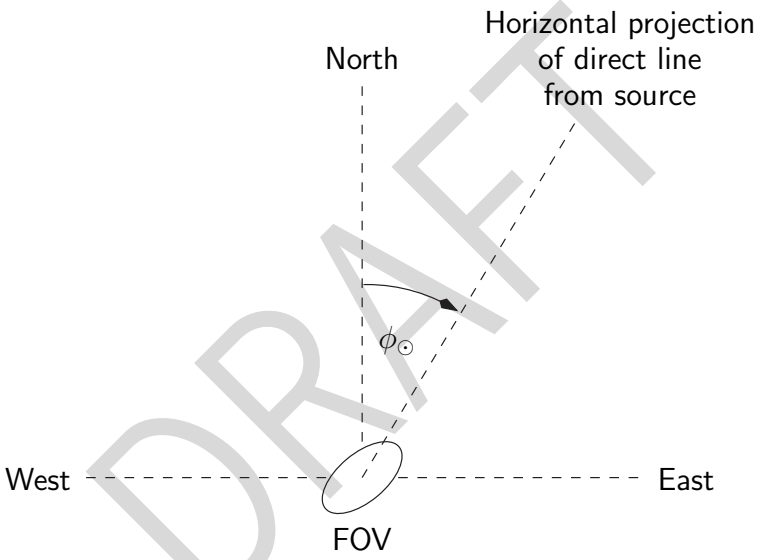


Figure A.12: Definition of `GeometryInfo` source azimuth angle component.

A.6.1 *CRTM_Compute_GeometryInfo interface*

```
NAME:
      CRTM_Compute_GeometryInfo

PURPOSE:
      Function to compute the derived geometry from the user specified
      components of the CRTM GeometryInfo structure.

CALLING SEQUENCE:
      Error_Status = CRTM_Compute_GeometryInfo( GeometryInfo           , &
                                                Message_Log=Message_Log  )

INPUT ARGUMENTS:
      GeometryInfo:  The GeometryInfo structure containing the user
                     defined inputs, in particular the angles.
                     UNITS:      N/A
                     TYPE:       CRTM_GeometryInfo_type
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(IN OUT)

OUTPUT ARGUMENTS:
      GeometryInfo:  The GeometryInfo structure with the derived
                     angle components filled..
                     UNITS:      N/A
                     TYPE:       CRTM_GeometryInfo_type
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:   Character string specifying a filename in which any
                     messages will be logged. If not specified, or if an
                     error occurs opening the log file, the default action
                     is to output messages to the screen.
                     UNITS:      N/A
                     TYPE:       CHARACTER( * )
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT( IN ), OPTIONAL

FUNCTION RESULT:
      Error_Status:   The return value is an integer defining the error status.
                      The error codes are defined in the ERROR_HANDLER module.
                      If == SUCCESS the computation was sucessful
                         == WARNING invalid data was found, but altered to default.
                         == FAILURE invalid data was found
                      UNITS:      N/A
                      TYPE:       INTEGER
                      DIMENSION:  Scalar

SIDE EFFECTS:
      This function changes the values of the derived components of the
      GeometryInfo structure argument.
```

A.6.2 *CRTM_RCS_ID_GeometryInfo interface*

```
NAME:
      CRTM_RCS_ID_GeometryInfo

PURPOSE:
      Subroutine to return the module RCS Id information.

CALLING SEQUENCE:
      CALL CRTM_RCS_Id_GeometryInfo( RCS_Id )

OUTPUT ARGUMENTS:
      RCS_Id:        Character string containing the Revision Control
                     System Id field for the module.
                     UNITS:      N/A
                     TYPE:       CHARACTER(*)
                     DIMENSION:  Scalar
                     ATTRIBUTES: INTENT(OUT)
```

A.7 RTSolution Structure

```
TYPE :: CRTM_RTSolution_type
  INTEGER :: n_Allocates = 0
  ! Dimensions
  INTEGER :: n_Layers = 0  ! K
  ! Internal variables. Users do not need to worry about these.
  LOGICAL :: Scattering_Flag = .TRUE.
  INTEGER :: n_Full_Streams  = 0
  INTEGER :: n_Stokes        = 0
  ! Forward radiative transfer intermediate results for a single channel
  !    These components are not defined when they are used as TL, AD
  !    and K variables
  REAL(fp) :: Surface_Emissivity      = ZERO
  REAL(fp) :: Up_Radiance             = ZERO
  REAL(fp) :: Down_Radiance           = ZERO
  REAL(fp) :: Down_Solar_Radiance     = ZERO
  REAL(fp) :: Surface_Planck_Radiance = ZERO
  REAL(fp), POINTER :: Upwelling_Radiance(:)  => NULL()  ! K
  ! The layer optical depths
  REAL(fp), POINTER :: Layer_Optical_Depth(:) => NULL()  ! K
  ! Radiative transfer results for a single channel/node
  REAL(fp) :: Radiance               = ZERO
  REAL(fp) :: Brightness_Temperature = ZERO
END TYPE CRTM_RTSolution_type
```

Figure A.13: CRTM_RTSolution_type structure definition.

Component	Description	Units	Dimensions
n_Layers	Number of atmospheric profile layers (K)	N/A	Scalar
Surface_Emissivity	The computed surface emissivity	N/A	Scalar
Up_Radiance	The atmospheric portion of the upwelling radiance	mW/(m^2.sr.cm^{-1})	Scalar
Down_Radiance	The atmospheric portion of the downwelling radiance	mW/(m^2.sr.cm^{-1})	Scalar
Down_Solar_Radiance	The downwelling direct solar radiance	mW/(m^2.sr.cm^{-1})	Scalar
Surface_Planck_Radiance	The surface radiance	mW/(m^2.sr.cm^{-1})	Scalar
Upwelling_Radiance	The upwelling radiance profile, including the reflected downwelling and surface contributions.	mW/(m^2.sr.cm^{-1})	K
Layer_Optical_Depth	The layer optical depth profile	N/A	K
Radiance	The sensor radiance	mW/(m^2.sr.cm^{-1})	Scalar
Brightness_Temperature	The sensor brightness temperature	Kelvin	Scalar

Table A.15: CRTM RTSolution structure component description

A.7.1 *CRTM_Associated_RTSolution interface*

```
NAME:
      CRTM_Associated_RTSolution

PURPOSE:
      Function to test the association status of the pointer members of a
      CRTM RTSolution structure.

CALLING SEQUENCE:
      Association_Status = CRTM_Associated_RTSolution( RTSolution       , &
                                                       ANY_Test=Any_Test  )

INPUT ARGUMENTS:
      RTSolution:          RTSolution structure which is to have its pointer
                           member's association status tested.
                           UNITS:      N/A
                           TYPE:       CRTM_RTSolution_type
                           DIMENSION:  Scalar, Rank-1, OR Rank-2 array
                           ATTRIBUTES: INTENT(IN)


OPTIONAL INPUT ARGUMENTS:
      ANY_Test:            Set this argument to test if ANY of the
                           RTSolution structure pointer members are associated.
                           The default is to test if ALL the pointer members
                           are associated.
                           If ANY_Test = 0, test if ALL the pointer members
                                            are associated.  (DEFAULT)
                              ANY_Test = 1, test if ANY of the pointer members
                                            are associated.
                           UNITS:      N/A
                           TYPE:       INTEGER
                           DIMENSION:  Scalar
                           ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Association_Status:  The return value is a logical value indicating the
                           association status of the RTSolution pointer
                           members.
                           .TRUE.  - if ALL the RTSolution pointer members
                                     are associated, or if the ANY_Test argument
                                     is set and ANY of the RTSolution
                                     pointer members are associated.
                           .FALSE. - some or all of the RTSolution pointer
                                     members are NOT associated.
                           UNITS:      N/A
                           TYPE:       LOGICAL
                           DIMENSION:  Same as input RTSolution argument
```

A.7.2 CRTM_Allocate_RTSolution interface

```
NAME:
      CRTM_Allocate_RTSolution

PURPOSE:
      Function to allocate the pointer members of the CRTM RTSolution
      data structure.

CALLING SEQUENCE:
      Error_Status = CRTM_Allocate_RTSolution( n_Layers               , &
                                               RTSolution             , &
                                               Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Layers:     Number of atmospheric layers
                    Must be > 0
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      RTSolution:   RTSolution structure with allocated pointer members.
                    Upon allocation, all pointer members are initialized to
                    a value of zero.

                    The following chart shows the allowable dimension
                    combinations for the calling routine, where
                      L == number of channels
                      M == number of profiles

                       Input          Output
                      n_Layers       RTSolution
                      dimension      dimension
                    ------------------------------
                       scalar         scalar
                       scalar      Rank-1 (L or M)
                       scalar      Rank-2 (L x M)

                    These multiple interfaces are supplied purely for ease of
                    use depending on how it's used.
                    UNITS:      N/A
                    TYPE:       CRTM_RTSolution_type
                    DIMENSION:  Scalar, Rank-1, or Rank-2
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
```

```
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to one (1) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output RTSolution argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.7.3 *CRTM_Destroy_RTSolution interface*

```
NAME:
      CRTM_Destroy_RTSolution

PURPOSE:
      Function to re-initialize the scalar and pointer members of a CRTM
      RTSolution data structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy_RTSolution( RTSolution             , &
                                              Message_Log=Message_Log  )

OUTPUT ARGUMENTS:
      RTSolution:   Re-initialized RTSolution structure.
                    UNITS:      N/A
                    TYPE:       CRTM_RTSolution_type
                    DIMENSION:  Scalar, Rank-1, or Rank-2
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    Messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output Messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
```

```
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to zero (0) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output RTSolution argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.7.4 CRTM_Assign_RTSolution interface

```
NAME:
      CRTM_Assign_RTSolution

PURPOSE:
      Function to copy valid CRTM RTSolution structures.

CALLING SEQUENCE:
      Error_Status = CRTM_Assign_RTSolution( RTSolution_in          , &
                                             RTSolution_out         , &
                                             Message_Log=Message_Log  )

INPUT ARGUMENTS:
      RTSolution_in:   RTSolution structure which is to be copied.
                       UNITS:      N/A
                       TYPE:       CRTM_RTSolution_type
                       DIMENSION:  Scalar, Rank-1, or Rank-2
                       ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      RTSolution_out:  Copy of the input structure, RTSolution_in.
                       UNITS:      N/A
                       TYPE:       CRTM_RTSolution_type
                       DIMENSION:  Same as input RTSolution_in
                       ATTRIBUTES: INTENT(IN OUT)
```

```
OPTIONAL INPUT ARGUMENTS:
      Message_Log:     Character string specifying a filename in which any
                       messages will be logged. If not specified, or if an
                       error occurs opening the log file, the default action
                       is to output messages to standard output.
                       UNITS:      N/A
                       TYPE:       CHARACTER(*)
                       DIMENSION:  Scalar
                       ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:    The return value is an integer defining the error status.
                       The error codes are defined in the Message_Handler module.
                       If == SUCCESS the structure assignment was successful
                          == FAILURE an error occurred
                       UNITS:      N/A
                       TYPE:       INTEGER
                       DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output RTSolution argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.7.5 CRTM_Equal_RTSolution interface

```
NAME:
      CRTM_Equal_RTSolution

PURPOSE:
      Function to test if two RTSolution structures are equal.

CALLING SEQUENCE:
      Error_Status = CRTM_Equal_RTSolution( RTSolution_LHS                      ,
                                            RTSolution_RHS                      ,
                                            ULP_Scale         =ULP_Scale        ,
                                            Percent_Difference=Percent_Difference,
                                            Check_All         =Check_All        ,
                                            Check_Intermediate=Check_Intermediate,
                                            Message_Log       =Message_Log


INPUT ARGUMENTS:
      RTSolution_LHS:     RTSolution structure to be compared; equivalent to the
                          left-hand side of a lexical comparison, e.g.
                            IF ( RTSolution_LHS == RTSolution_RHS ).
                          UNITS:      N/A
                          TYPE:       CRTM_RTSolution_type
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN)
```

```
      RTSolution_RHS:     RTSolution structure to be compared to; equivalent to
                          right-hand side of a lexical comparison, e.g.
                            IF ( RTSolution_LHS == RTSolution_RHS ).
                          UNITS:      N/A
                          TYPE:       CRTM_RTSolution_type
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ULP_Scale:          Unit of data precision used to scale the floating
                          point comparison. ULP stands for "Unit in the Last Place,"
                          the smallest possible increment or decrement that can be
                          made using a machine's floating point arithmetic.
                          Value must be positive - if a negative value is supplied,
                          the absolute value is used. If not specified, the default
                          value is 1.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

      Percent_Differnece: Percentage difference value to use in comparing
                          the numbers rather than testing within some numerical
                          limit. The ULP_Scale argument is ignored if this argument is
                          specified.
                          UNITS:      N/A
                          TYPE:       REAL(fp)
                          DIMENSION:  Scalar
                          ATTRIBUTES: OPTIONAL, INTENT(IN)

      Check_All:          Set this argument to check ALL the floating point
                          channel data of the RTSolution structures. The default
                          action is return with a FAILURE status as soon as
                          any difference is found. This optional argument can
                          be used to get a listing of ALL the differences
                          between data in RTSolution structures.
                          If == 0, Return with FAILURE status as soon as
                                   ANY difference is found  *DEFAULT*
                             == 1, Set FAILURE status if ANY difference is
                                   found, but continue to check ALL data.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

      Check_Intermediate: Set this argument to check the intermediate results held
                          in the RTSolution structure. The default action does NOT
                          check these components.
                          If == 0, Intermediate result components not checked
                                   for equality.  *DEFAULT*
                             == 1, Intermediate result components ARE checked
                                   for equality. Note that this could generate
                                   a lot of comparison failures.
```

```
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:        Character string specifying a filename in which any
                          messages will be logged. If not specified, or if an
                          error occurs opening the log file, the default action
                          is to output messages to standard output.
                          UNITS:      None
                          TYPE:       CHARACTER(*)
                          DIMENSION:  Scalar
                          ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:       The return value is an integer defining the error status.
                          The error codes are defined in the Message_Handler module.
                          If == SUCCESS the structures were equal
                             == FAILURE - an error occurred, or
                                        - the structures were different.
                          UNITS:      N/A
                          TYPE:       INTEGER
                          DIMENSION:  Scalar
```

A.7.6 CRTM_RCS_ID_RTSolution interface

```
NAME:
      CRTM_RCS_ID_RTSolution

PURPOSE:
      Subroutine to return the module RCS Id information.

CALLING SEQUENCE:
      CALL CRTM_RCS_Id_RTSolution( RCS_Id )

OUTPUT ARGUMENTS:
      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(OUT)
```

A.7.7 CRTM_Inquire_RTSolution_Binary interface

```
NAME:
      CRTM_Inquire_RTSolution_Binary
```

```
PURPOSE:
      Function to inquire Binary format CRTM RTSolution structure files.

CALLING SEQUENCE:
      Error_Status = CRTM_Inquire_RTSolution_Binary( Filename               , &
                                                     n_Channels =n_Channels , &
                                                     n_Profiles =n_Profiles , &
                                                     RCS_Id     =RCS_Id     , &
                                                     Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an
                    RTSolution format data file to read.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      n_Channels:   The number of spectral channels for which there is
                    data in the file. Note that this value will always
                    be 0 for a profile-only RTSolution dataset-- it only
                    has meaning for K-matrix RTSolution data.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

      n_Profiles:   The number of atmospheric profiles in the data file.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:       Character string containing the version control Id
                    field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
```

```
                  The error codes are defined in the Message_Handler module.
                  If == SUCCESS the Binary file inquire was successful
                     == FAILURE an unrecoverable error occurred.
                  UNITS:      N/A
                  TYPE:       INTEGER
                  DIMENSION:  Scalar
```

A.7.8 CRTM_Read_RTSolution_Binary interface

```
NAME:
      CRTM_Read_RTSolution_Binary

PURPOSE:
      Function to read Binary format CRTM RTSolution structure files.

CALLING SEQUENCE:
      Error_Status = CRTM_Read_RTSolution_Binary( Filename               , &
                                                  RTSolution             , &
                                                  Quiet      =Quiet      , &
                                                  n_Channels =n_Channels , &
                                                  n_Profiles =n_Profiles , &
                                                  RCS_Id     =RCS_Id     , &
                                                  Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an
                    RTSolution format data file to read.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      RTSolution:   Structure array containing the RTSolution data. Note
                    the rank is CHANNELS x PROFILES.
                    UNITS:      N/A
                    TYPE:       CRTM_RTSolution_type
                    DIMENSION:  Rank-2 (L x M)
                    ATTRIBUTES: INTENT(IN OUT)


OPTIONAL INPUT ARGUMENTS:
      Quiet:        Set this argument to suppress INFORMATION messages
                    being printed to standard output (or the message
                    log file if the Message_Log optional argument is
                    used.) By default, INFORMATION messages are printed.
                    If QUIET = 0, INFORMATION messages are OUTPUT.
                       QUIET = 1, INFORMATION messages are SUPPRESSED.
                    UNITS:      N/A
                    TYPE:       INTEGER
```

```
                  DIMENSION:  Scalar
                  ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      n_Channels:   The number of channels for which data was read.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

      n_Profiles:   The number of profiles for which data was read.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

      RCS_Id:       Character string containing the version control Id
                    field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the Binary file read was successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output RTSolution argument is IN OUT rather
      than just OUT. This is necessary because the argument may be defined on
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.7.9 CRTM_Write_RTSolution_Binary interface

```
NAME:
      CRTM_Write_RTSolution_Binary
```

```
PURPOSE:
      Function to write Binary format RTSolution files.

CALLING SEQUENCE:
      Error_Status = CRTM_Write_RTSolution_Binary( Filename               , &
                                                   RTSolution             , &
                                                   Quiet      =Quiet      , &
                                                   RCS_Id     =RCS_Id     , &
                                                   Message_Log=Message_Log  )

INPUT ARGUMENTS:
      Filename:     Character string specifying the name of an output
                    RTSolution format data file.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

      RTSolution:   Structure containing the RTSolution data to write.
                    Note the rank is CHANNELS x PROFILES.
                    UNITS:      N/A
                    TYPE:       CRTM_RTSolution_type
                    DIMENSION:  Rank-2 (L x M)
                    ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      Quiet:        Set this argument to suppress INFORMATION messages
                    being printed to standard output (or the message
                    log file if the Message_Log optional argument is
                    used.) By default, INFORMATION messages are printed.
                    If QUIET = 0, INFORMATION messages are OUTPUT.
                       QUIET = 1, INFORMATION messages are SUPPRESSED.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:  Character string specifying a filename in which any
                    messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

OPTIONAL OUTPUT ARGUMENTS:
      RCS_Id:       Character string containing the version control Id
                    field for the module.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: OPTIONAL, INTENT(OUT)
```

```
FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the Binary file write was successful
                       == FAILURE an unrecoverable error occurred.
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar

SIDE EFFECTS:
      - If the output file already exists, it is overwritten.
      - If an error occurs *during* the write phase, the output file is deleted
        before returning to the calling routine.
```

A.8 `Options` Structure

```
TYPE :: CRTM_Options_type
  INTEGER :: n_Allocates = 0
  ! Dimensions
  INTEGER :: n_Channels = 0  ! L dimension
  ! Index into channel-specific components
  INTEGER :: Channel = 0
  ! Emissivity optional arguments
  INTEGER           :: Emissivity_Switch =  NOT_SET
  REAL(fp), POINTER :: Emissivity(:)     => NULL() ! L
  ! Direct reflectivity optional arguments
  INTEGER           :: Direct_Reflectivity_Switch =  NOT_SET
  REAL(fp), POINTER :: Direct_Reflectivity(:)     => NULL() ! L
  ! Antenna correction application
  INTEGER :: Antenna_Correction = NOT_SET
END TYPE CRTM_Options_type
```

Figure A.14: CRTM_Options_type structure definition.

Component	Description	Units	Dimensions
`n_Channels`	Number of sensor channels (`L`).	N/A	Scalar
`Channel`	Index into channel-specific components.	N/A	Scalar
`Emissivity_Switch`	Switch to apply user-defined surface emissivity. Valid values: `NOT_SET`: Calculate emissivity (default). `SET`: Use user-defined emissivity	N/A	Scalar
`Emissivity`	User-defined surface emissivity for each sensor channel.	N/A	`L`
`Direct_Reflectivity_Switch`	Switch to apply user-defined reflectivity for downwelling source (e.g. solar). This switch is ignored unless the `Emissivity_Switch` is also set. Valid values: `NOT_SET`: Calculate reflectivity (default). `SET`: Use user-defined reflectivity	N/A	Scalar
`Direct_Reflectivity`	User-defined direct reflectivity for downwelling source for each sensor channel.	N/A	`L`
`Antenna_Correction`	Switch to apply antenna correction for select microwave instruments.	N/A	Scalar

Table A.16: CRTM `Options` structure component description

A.8.1 CRTM_Associated_Options interface

```
NAME:
      CRTM_Associated_Options

PURPOSE:
      Function to test the association status of the pointer members of a
      CRTM Options structure.

CALLING SEQUENCE:
      Association_Status = CRTM_Associated_Options( Options          , &
                                                    ANY_Test=Any_Test  )

INPUT ARGUMENTS:
      Options:             Options structure which is to have its pointer
                           member's association status tested.
                           UNITS:      N/A
                           TYPE:       CRTM_Options_type
                           DIMENSION:  Scalar or Rank-1 array
                           ATTRIBUTES: INTENT(IN)

OPTIONAL INPUT ARGUMENTS:
      ANY_Test:            Set this argument to test if ANY of the
                           Options structure pointer members are associated.
                           The default is to test if ALL the pointer members
                           are associated.
                           If ANY_Test = 0, test if ALL the pointer members
                                            are associated.  (DEFAULT)
                              ANY_Test = 1, test if ANY of the pointer members
                                            are associated.
                           UNITS:      N/A
                           TYPE:       INTEGER
                           DIMENSION:  Scalar
                           ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Association_Status:  The return value is a logical value indicating the
                           association status of the Options pointer
                           members.
                           .TRUE.  - if ALL the Options pointer members
                                     are associated, or if the ANY_Test argument
                                     is set and ANY of the Options
                                     pointer members are associated.
                           .FALSE. - some or all of the Options pointer
                                     members are NOT associated.
                           UNITS:      N/A
                           TYPE:       LOGICAL
                           DIMENSION:  Same as input Options argument
```

A.8.2 *CRTM_Allocate_Options interface*

```
NAME:
      CRTM_Allocate_Options

PURPOSE:
      Function to allocate the pointer members of a CRTM Options
      data structure.

CALLING SEQUENCE:
      Error_Status = CRTM_Allocate_Options( n_Channels             , &
                                            Options                , &
                                            Message_Log=Message_Log  )

INPUT ARGUMENTS:
      n_Channels:   Number of sensor channels
                    Must be > 0
                    UNITS:      N/A
                    TYPE:       INTEGER
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN)

OUTPUT ARGUMENTS:
      Options:      Options structure with allocated pointer members.
                    Upon allocation, all pointer members are initialized to
                    a value of zero.
                    UNITS:      N/A
                    TYPE:       CRTM_Options_type
                    DIMENSION:  Scalar or Rank-1
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    Messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output Messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure pointer allocations were
                                  successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to one (1) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
```

```
                  TYPE:       INTEGER
                  DIMENSION:  Scalar

COMMENTS:
      Note the INTENT on the output Options argument is IN OUT rather than
      just OUT. This is necessary because the argument may be defined upon
      input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.8.3 *CRTM_Destroy_Options interface*

```
NAME:
      CRTM_Destroy_Options

PURPOSE:
      Function to re-initialize the scalar and pointer members of a CRTM
      Options data structure.

CALLING SEQUENCE:
      Error_Status = CRTM_Destroy_Options( Options              , &
                                           Message_Log=Message_Log  )

OUTPUT ARGUMENTS:
      Options:      Re-initialized Options structure.
                    UNITS:      N/A
                    TYPE:       CRTM_Options_type
                    DIMENSION:  Scalar or Rank-1
                    ATTRIBUTES: INTENT(IN OUT)

OPTIONAL INPUT ARGUMENTS:
      Message_Log:  Character string specifying a filename in which any
                    Messages will be logged. If not specified, or if an
                    error occurs opening the log file, the default action
                    is to output Messages to standard output.
                    UNITS:      N/A
                    TYPE:       CHARACTER(*)
                    DIMENSION:  Scalar
                    ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status: The return value is an integer defining the error status.
                    The error codes are defined in the Message_Handler module.
                    If == SUCCESS the structure re-initialisation was successful
                       == FAILURE - an error occurred, or
                                  - the structure internal allocation counter
                                    is not equal to zero (0) upon exiting this
                                    function. This value is incremented and
                                    decremented for every structure allocation
                                    and deallocation respectively.
                    UNITS:      N/A
                    TYPE:       INTEGER
```

```
                    DIMENSION:  Scalar

  COMMENTS:
        Note the INTENT on the output Options argument is IN OUT rather than
        just OUT. This is necessary because the argument may be defined upon
        input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.8.4 CRTM_Assign_Options interface

```
  NAME:
        CRTM_Assign_Options

  PURPOSE:
        Function to copy valid CRTM Options structures.

  CALLING SEQUENCE:
        Error_Status = CRTM_Assign_Options( Options_in           , &
                                            Options_out          , &
                                            Message_Log=Message_Log  )

  INPUT ARGUMENTS:
        Options_in:      Options structure which is to be copied.
                         UNITS:      N/A
                         TYPE:       CRTM_Options_type
                         DIMENSION:  Scalar or Rank-1
                         ATTRIBUTES: INTENT(IN)

  OUTPUT ARGUMENTS:
        Options_out:     Copy of the input structure, Options_in.
                         UNITS:      N/A
                         TYPE:       CRTM_Options_type
                         DIMENSION:  Same as Options_in
                         ATTRIBUTES: INTENT(IN OUT)

  OPTIONAL INPUT ARGUMENTS:
        Message_Log:     Character string specifying a filename in which any
                         Messages will be logged. If not specified, or if an
                         error occurs opening the log file, the default action
                         is to output Messages to standard output.
                         UNITS:      N/A
                         TYPE:       CHARACTER(*)
                         DIMENSION:  Scalar
                         ATTRIBUTES: INTENT(IN), OPTIONAL

  FUNCTION RESULT:
        Error_Status:    The return value is an integer defining the error status.
                         The error codes are defined in the Message_Handler module.
                         If == SUCCESS the structure assignment was successful
                            == FAILURE an error occurred
                         UNITS:      N/A
```

```
                        TYPE:       INTEGER
                        DIMENSION:  Scalar

  COMMENTS:
        Note the INTENT on the output Options argument is IN OUT rather than
        just OUT. This is necessary because the argument may be defined upon
        input. To prevent memory leaks, the IN OUT INTENT is a must.
```

A.8.5 CRTM_Equal_Options interface

```
  NAME:
        CRTM_Equal_Options

  PURPOSE:
        Function to test if two CRTM Options structures are equal.

  CALLING SEQUENCE:
        Error_Status = CRTM_Equal_Options( Options_LHS           , &
                                           Options_RHS           , &
                                           ULP_Scale  =ULP_Scale  , &
                                           Check_All  =Check_All  , &
                                           Message_Log=Message_Log  )


  INPUT ARGUMENTS:
        Options_LHS:         Options structure to be compared; equivalent to the
                             left-hand side of a lexical comparison, e.g.
                               IF ( Options_LHS == Options_RHS ).
                             In the context of the CRTM, rank-1 corresponds to an
                             vector of profiles.
                             UNITS:      N/A
                             TYPE:       CRTM_Options_type
                             DIMENSION:  Scalar or Rank-1 array
                             ATTRIBUTES: INTENT(IN)

        Options_RHS:         Options structure to be compared to; equivalent to
                             right-hand side of a lexical comparison, e.g.
                               IF ( Options_LHS == Options_RHS ).
                             UNITS:      N/A
                             TYPE:       CRTM_Options_type
                             DIMENSION:  Same as Options_LHS
                             ATTRIBUTES: INTENT(IN)

  OPTIONAL INPUT ARGUMENTS:
        ULP_Scale:           Unit of data precision used to scale the floating
                             point comparison. ULP stands for "Unit in the Last Place,"
                             the smallest possible increment or decrement that can be
                             made using a machine's floating point arithmetic.
                             Value must be positive - if a negative value is supplied,
                             the absolute value is used. If not specified, the default
```

```
                        value is 1.
                        UNITS:      N/A
                        TYPE:       INTEGER
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

      Check_All:        Set this argument to check ALL the floating point
                        channel data of the Options structures. The default
                        action is return with a FAILURE status as soon as
                        any difference is found. This optional argument can
                        be used to get a listing of ALL the differences
                        between data in Options structures.
                        If == 0, Return with FAILURE status as soon as
                                 ANY difference is found  *DEFAULT*
                           == 1, Set FAILURE status if ANY difference is
                                 found, but continue to check ALL data.
                        UNITS:      N/A
                        TYPE:       INTEGER
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

      Message_Log:      Character string specifying a filename in which any
                        messages will be logged. If not specified, or if an
                        error occurs opening the log file, the default action
                        is to output messages to standard output.
                        UNITS:      None
                        TYPE:       CHARACTER(*)
                        DIMENSION:  Scalar
                        ATTRIBUTES: INTENT(IN), OPTIONAL

FUNCTION RESULT:
      Error_Status:     The return value is an integer defining the error status.
                        The error codes are defined in the Message_Handler module.
                        If == SUCCESS the structures were equal
                           == FAILURE - an error occurred, or
                                      - the structures were different.
                        UNITS:      N/A
                        TYPE:       INTEGER
                        DIMENSION:  Scalar
```


A.8.6 CRTM_RCS_ID_Options interface

```
NAME:
      CRTM_RCS_ID_Options

PURPOSE:
      Subroutine to return the module RCS Id information.

CALLING SEQUENCE:
      CALL CRTM_RCS_Id_Options( RCS_Id )
```

```
OUTPUT ARGUMENTS:
      RCS_Id:         Character string containing the Revision Control
                      System Id field for the module.
                      UNITS:      N/A
                      TYPE:       CHARACTER(*)
                      DIMENSION:  Scalar
                      ATTRIBUTES: INTENT(OUT)
```

B Valid Sensor Identifiers

B.1 Infrared instruments

Instrument	Sensor Id	Instrument	Sensor Id
Aqua AIRS (281ch. subset)	airs281_aqua	NOAA-16 HIRS/3	hirs3_n16
Aqua AIRS (324ch. subset)	airs324_aqua	NOAA-17 HIRS/3	hirs3_n17
Aqua AIRS Module-1a	airsM1a_aqua	NOAA-18 HIRS/4	hirs4_n18
Aqua AIRS Module-1b	airsM1b_aqua	MetOp-A HIRS/4	hirs4_metop-a
Aqua AIRS Module-2a	airsM2a_aqua	NOAA-19 HIRS/4	hirs4_n19
Aqua AIRS Module-2b	airsM2b_aqua	MetOp-A IASI (300ch. subset)	iasi300_metop-a
Aqua AIRS Module-3	airsM3_aqua	MetOp-A IASI (316ch. subset)	iasi316_metop-a
Aqua AIRS Module-4a	airsM4a_aqua	MetOp-A IASI (616ch. subset)	iasi616_metop-a
Aqua AIRS Module-4b	airsM4b_aqua	MetOp-A IASI Band 1	iasiB1_metop-a
Aqua AIRS Module-4c	airsM4c_aqua	MetOp-A IASI Band 2	iasiB2_metop-a
Aqua AIRS Module-4d	airsM4d_aqua	MetOp-A IASI Band 3	iasiB3_metop-a
Aqua AIRS Module-5	airsM5_aqua	MetOp-A IASI	iasi_metop-a
Aqua AIRS Module-6	airsM6_aqua	NPP CrIS Band 1	crisB1_npp
Aqua AIRS Module-7	airsM7_aqua	NPP CrIS Band 2	crisB2_npp
Aqua AIRS Module-8	airsM8_aqua	NPP CrIS Band 3	crisB3_npp
Aqua AIRS Module-9	airsM9_aqua	GOES-08 Imager	imgr_g08
Aqua AIRS Module-10	airsM10_aqua	GOES-09 Imager	imgr_g09
Aqua AIRS Module-11	airsM11_aqua	GOES-10 Imager	imgr_g10
Aqua AIRS Module-12	airsM12_aqua	GOES-11 Imager	imgr_g11
Aqua AIRS	airs_aqua	GOES-12 Imager	imgr_g12
TIROS-N AVHRR/2	avhrr2_tirosn	GOES-13 Imager	imgr_g13
NOAA-06 AVHRR/2	avhrr2_n06	GOES-R ABI	abi_gr
NOAA-07 AVHRR/2	avhrr2_n07	MTSAT-1R Imager	imgr_mt1r
NOAA-08 AVHRR/2	avhrr2_n08	Aqua MODIS	modis_aqua
NOAA-09 AVHRR/2	avhrr2_n09	Terra MODIS	modis_terra
NOAA-10 AVHRR/2	avhrr2_n10	MeteoSat-08 SEVIRI	seviri_m08
NOAA-11 AVHRR/2	avhrr2_n11	MeteoSat-09 SEVIRI	seviri_m09
NOAA-12 AVHRR/2	avhrr2_n12	MeteoSat-10 SEVIRI	seviri_m10
NOAA-14 AVHRR/2	avhrr2_n14	GOES-08 Sounder	sndr_g08
NOAA-15 AVHRR/3	avhrr3_n15	GOES-09 Sounder	sndr_g09
NOAA-16 AVHRR/3	avhrr3_n16	GOES-10 Sounder	sndr_g10
NOAA-17 AVHRR/3	avhrr3_n17	GOES-11 Sounder	sndr_g11
NOAA-18 AVHRR/3	avhrr3_n18	GOES-12 Sounder	sndr_g12
MetOp-A AVHRR/3	avhrr3_metop-a	GOES-13 Sounder	sndr_g13
NOAA-19 AVHRR/3	avhrr3_n19	TIROS-N SSU	ssu_tirosn
TIROS-N HIRS/2	hirs2_tirosn	NOAA-06 SSU	ssu_n06
NOAA-06 HIRS/2	hirs2_n06	NOAA-07 SSU	ssu_n07
NOAA-07 HIRS/2	hirs2_n07	NOAA-08 SSU	ssu_n08
NOAA-08 HIRS/2	hirs2_n08	NOAA-09 SSU	ssu_n09
NOAA-09 HIRS/2	hirs2_n09	NOAA-10 SSU	ssu_n11
NOAA-10 HIRS/2	hirs2_n10	NOAA-11 SSU	ssu_n14
NOAA-11 HIRS/2	hirs2_n11	GMS-5 VISSR (Detector A)	vissrDetA_gms5
NOAA-12 HIRS/2	hirs2_n12	Fengyun-3A VIRR	virr_fy3a
NOAA-14 HIRS/2	hirs2_n14	Fengyun-3A IRAS	iras_fy3a
NOAA-15 HIRS/3	hirs3_n15	Fengyun-3A MERSI	mersi_fy3a

Table B.1: CRTM sensor identifiers for infrared instruments.

B.2 Microwave instruments

Instrument	Sensor Id	Instrument	Sensor Id
Aqua AMSR-E	amsre_aqua	MetOp-A MHS	mhs_metop-a
Aqua AMSU-A	amsua_aqua	MetOp-B MHS	mhs_metop-b
Aqua HSB	hsb_aqua	MetOp-C MHS	mhs_metop-c
TIROS-N MSU	msu_tirosn	DMSP-08 SSM/I	ssmi_f08
NOAA-06 MSU	msu_n06	DMSP-10 SSM/I	ssmi_f10
NOAA-07 MSU	msu_n07	DMSP-11 SSM/I	ssmi_f11
NOAA-08 MSU	msu_n08	DMSP-13 SSM/I	ssmi_f13
NOAA-09 MSU	msu_n09	DMSP-14 SSM/I	ssmi_f14
NOAA-10 MSU	msu_n10	DMSP-15 SSM/I	ssmi_f15
NOAA-11 MSU	msu_n11	DMSP-13 SSM/T-1	ssmt1_f13
NOAA-12 MSU	msu_n12	DMSP-15 SSM/T-1	ssmt1_f15
NOAA-14 MSU	msu_n14	DMSP-14 SSM/T-2	ssmt2_f14
NOAA-15 AMSU-A	amsua_n15	DMSP-15 SSM/T-2	ssmt2_f15
NOAA-16 AMSU-A	amsua_n16	DMSP-16 SSMIS	ssmis_f16
NOAA-17 AMSU-A	amsua_n17	DMSP-17 SSMIS	ssmis_f17
NOAA-18 AMSU-A	amsua_n18	DMSP-18 SSMIS	ssmis_f18
NOAA-19 AMSU-A	amsua_n19	DMSP-19 SSMIS	ssmis_f19
MetOp-A AMSU-A	amsua_metop-a	DMSP-20 SSMIS	ssmis_f20
MetOp-B AMSU-A	amsua_metop-b	NPP ATMS	atms_npp
MetOp-C AMSU-A	amsua_metop-c	Coriolis WindSat	windsat_coriolis
NOAA-15 AMSU-B	amsub_n15	TRMM TMI	tmi_trmm
NOAA-16 AMSU-B	amsub_n16	GPM GMI	gmi_gpm
NOAA-17 AMSU-B	amsub_n17	Fengyun-3A MWRI	mwri_fy3a
NOAA-18 MHS	mhs_n18	Fengyun-3A MWHS	mwhs_fy3a
NOAA-19 MHS	mhs_n19	Fengyun-3A MWTS	mwts_fy3a

Table B.2: CRTM sensor identifiers for microwave instruments.

C Utility Software Description

C.1 `Type_Kinds` Module

C.2 `File_Utility` Module

C.3 `Message_Handler` Module