

NWP SAF	RTTOV8 Top Level Design	Doc ID : NWPSAF-MO-DS-002 Version : 1.2 Date : 28/4/2004
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RTTOV-8 TOP LEVEL DESIGN

Pascal Brunel
MétéoFrance
 &
Roger Saunders & Andrew Smith
Met Office

This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 25 November 1998, between EUMETSAT and the Met Office, UK, by one or more partners within the NWP SAF. The partners in the NWP SAF are the Met Office, ECMWF, KNMI and Météo France.

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Change record			
Version	Date	Author / changed by	Remarks
1.0	17/12/02	P. Brunel	Initial draft
1.1	8/03/04	R. Saunders	Updated for final RTTOV-8 code
1.2	28/04/04	R. Saunders	Final updates

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1. Introduction and scope

The purpose of this report is to document the main functional elements of RTTOV-8. It shows the modular structure of the software, including the function of each module and the data-flow between modules. A users guide is available for an overview and installation of RTTOV-8 on to a users computer system. Scientific and validation documentation can be found in the RTTOV-8 scientific and validation report. This report may be updated from time to time. Updates will be published on the NWP-SAF web site on the RTTOV-8 page at:

<http://www.metoffice.com/research/interproj/nwpsaf/rtm/> along with all the other documentation.

The code, scripts, test files and coefficient files are available either via ftp (as a compressed UNIX tar file) or on a CD-ROM from ECMWF data services.

2. RTTOV-8 design

2.1 RTTOV-8 package overview

The model is only available in standard Fortran 90 code and unix scripts are prepared to run the test code supplied with the model. The FORTRAN 90 standard defined in Andrews *et. al.* (1995) '*European Standards for Writing and Documenting Exchangeable Fortran 90 Code*' has been followed wherever possible. The subroutine headers contain documentation on the input/output variables and so the user should study these headers to get details of the interface between modules. An overall routine calling tree is given in Figures 1 to ???. The code has been optimised for vector machines and also made threadsafe for MPP platforms. It has been tested on the following platforms: HP, SGI, Cray T3E, Fujitsu VPP, SUN, Linux intel PC and compiler options for these are supplied in the Makefile. Annex A gives a more complete list of platforms and compilers on which the code has been tested.

The RTTOV-8 package delivered to the user consists of :

- a self contained library of Fortran90 subroutines, interface and modules
- a makefile to compile the code
- a set of main programs for testing various aspects
- a set of testing scripts, at least one per instrument
- a set of coefficient files
- a set of input files required for testing
- a set of reference test results
- a set of documentation

All the above are provided as a tar file to the user.

2.2 Functionality

2.2.1 Managing computer resources

The major requirement for RTTOV-8 is to allow the user to be able to run the code without limits for the number of channels, profiles and instruments in the same run. This has been established by using arrays of derived types and dynamic memory allocation. Derived types reduce the number of arguments to be passed to the subroutines and facilitates the memory allocation of the arrays (sequence of allocation for all derived arrays of one derived type). The remaining limits are given by:

- the external RTTOV coefficient file which contains the number of fixed pressure levels on which the user has to provide the atmospheric profiles.
- the size of the computer physical memory

The user can allocate all the derived types which are arguments of the subroutines (coefficients, profiles, radiances, channels...). In this way the user can run inside the same main program calls for different instruments for which the reference profiles can be on different pressure levels.

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2.2.2 Managing coefficient files

The user manages the RTTOV coefficients within his program and is responsible for allocating the maximum number of instruments for the run. He calls the RTTOV coefficient file ingest module *rttov_read_coef* with the characteristics of the satellite and instrument, or with a filename and with a list of selected channels, or all channels are considered. *rttov_read_coef* reads the data and allocates memory for the storage. *rttov_dealloc_coef* will allow the user to de-allocate memory for the coefficients. The *rttov_ascii2bin_coef* module enables the user to create a coefficient set in a binary form which allow for more efficient input in RTTOV-8 especially for large coefficient files for advanced IR sounders.

2.2.3 Management of atmospheric profiles

The user should provide RTTOV with atmospheric profiles in the form of atmospheric structures. Pressure levels are not fixed but should be the same as in the supplied coefficients file. The values of the profile will be checked according to the limits given by the coefficient file. The pressure levels will be checked according to the values of the reference profile of the coefficient file. The user has to provide a list of profile indices for each calculated radiance. The user has to provide a list of channel indices for each calculated radiance.

2.2.3 Management of instrument channels

The user has to provide the model with a list of channel numbers for each calculated radiance. The definition of the channel numbers is provided in the coefficient file for each instrument. The user will be informed if an invalid channel number is provided. The polarisation index of each channel must also be specified.

2.2.4 Emissivities

The model is able to compute IR (over ocean) and MW emissivities according to some surface input parameters. The user has to provide a logical array indicating for which channel and profile he wants the model to calculate emissivities. The emissivity models used in RTTOV-8 are SSIREM (IR) and FASTEM versions 2 and 3 (MW). The emissivities computed by the model are returned in the output arrays from RTTOV. *Note that one difference with RTTOV-7 is that the emissivities for individual polarisations are returned not the 'mixed' value.*

2.2.5 Physical units

Inside the code and for the user interface physical units used are:

- Pressure: hPa
- Atmospheric temperature: Kelvin
- Radiances: $\text{mW/cm}^2/\text{ster/m}^2$
- Equivalent black body brightness temperature: Kelvin
- Gas mixing ratio: ppmv: *Note this is different from RTTOV-7*
- Cloud cover, cloud fraction: [0,1] 0 for cloud free
- Surface wind vector u and v in m/s.
- Cloud liquid water, ice water, rain, solid precipitation: kg/kg
- Angles: degrees (0° - 360°) East = 90° .

2.2.6 Input and output

The *rttov-8* module accepts as input:

- The total number of calculated brightness temps per call
(ie $\text{nbts} \times \text{nprof}$) = nfrequencies

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- The number of calculated radiances required to be computed internally (e.g. for a microwave channel this is no. of polarisations required \times no. of frequencies) - `nchannels`
- The number of calculated brightness temperatures returned for each call – (ie `nbt \times nprof`) = `nbtout`
- The number of profiles per call - `nprof`
- The set of required channels indices (should match coeff file indices) – `channels`
- The set of required polarisation indices (should match coeff file indices) - `polarisations`
- List of profile indices for each channel and profile (size `nfrequencies`) - `lprofiles`
- Input atmospheric profiles - `profiles` (size `nprofiles`)
- a set of surface emissivities (size `nchannels`)
- a logical array `calcemiss` for selecting emissivity calculation if true (size `nchannels`)

The outputs are arrays of :

- surface to space transmittances (`nchannels`)
- layer to space transmittances (`levels`, `nchannels`)
- overcast radiances at given cloud top (`levels`, `nchannels`)
- overcast radiance from cloud top (`levels`, `nchannels`)
- clear, full cloudy, cloudy radiances (`nchannels`)
- clear, cloudy brightness temperatures (`nchannels`)
- output clear, cloudy brightness temperatures (`nbtout`)

The only input files required are the coefficient files that are assumed to be in the same directory as the program is run or better a link of the same name as the coefficient file. For the clear air and cloudy codes only 1 coefficient file per sensor is required but for the scattering code an additional coefficient file must be read.

3. RTTOV structures

Structures are used to define new derived data types that will make the code lighter and easier to read. One structure stores related data like all information needed to describe an atmospheric profile. All variable arrays are *defined as pointers* and are allocated at the run time according to the environment, there is no more need to declare parameters for the maximum size of arrays.

Defined structures are:

`profile_type` atmospheric profile including surface, viewing angle
`profile_cloud_type` information on clouds on atmospheric pressure levels
`rttov_coef` all coefficient data present in a coefficient file plus derived variables
`rttov_scatt_coef` Storage for RTTOV_SCATT coeffs
`profile_aux` derived profile information like nearest cloud top pressure level
`predictors_type` definition of predictors for one gas, one profile
`geometry_type` definition of detailed viewing geometry for one profile
`radiance_type` radiances and corresponding brightness temperature
`radiance_cloud_type` same as above plus cloud specific radiances
`radiance_aux` auxillary calculation arrays for RTE integration
`profile_scatt_aux` Auxillary profile variables for RTTOV_SCATT

The full definition of these arrays is given in Annex K of the user guide.

3.1 RTTOV modules design overview

RTTOV-8 model is made of 6 user's level modules, 2 for the coefficient management, one for each of the direct model TL, AD, K and RTTOV_CLD and RTTOV_SCATT.

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The modules for the coefficient management are:

- module to read the coefficients
- module to de-allocate the coefficient derived type

The direct model module contains sequentially:

- module to control the input profile with the coefficient limits
- module to calculate some auxiliary parameters from the input profile, like geometry angles
- modules to calculate the optical depth predictors for RTTOV-7 or 8
- module to calculate optical depth and transmittances
- modules to calculate surface emissivity
- module to compute the single brightness temperature from up to 4 separate polarisations
- module to integrate the radiative transfer equation

RTTOV_cld needs some additional modules

- Module to interpolate input profiles on NWP pressure levels to fixed coefficients levels
- Module to interpolate layer radiances to NWP levels
- Module to compute cloud emissivities
- Module to compute cloud radiance weights

RTTOV_scatt needs some additional modules

- Module to read the Mie coefficients
- Module to interpolate input profiles on NWP pressure levels to fixed coefficients levels
- Module to perform initialisations for delta-eddington
- Module to calculate scattering parameters from Mie tables
- Module to perform delta-eddington calculations

The TL model is based on the forward model, all functionalities are the same for all modules. They are all delivering the tangent linear as an additional output.

The AD and K first reproduce the direct model, to get the forward “trace” and then respectively all AD or K modules are called in the reverse sequence order.

The sequence order of the modules is defined in the chapter relative to the modules data-flow.

The update of new coefficients or instrument parameters is managed outside RTTOV by creating or updating the coefficient files. They are delivered in ASCII format for better portability. New science in the coefficient generation may induce changes inside the RTTOV code. For RTTOV-8 there are two options for predictors (so called RTTOV-7 and RTTOV-8 predictors). The selection of which code is run is managed by flags in the coefficient file.

3.2 RTTOV Setup functions

In all RTTOV functions, local arrays are dynamic arrays which dimensions are given by arguments (levels, channels, profiles, predictors).

rttov_setup (setup_errorstatus, Err_unit, verbosity_level, nrttovid, coef, instrument, ichan)

Calls routines below to simplify things for user.

rttov_errorhandling (Err_Unit, verbosity_level)

Sets up error message handling

Rttov_readcoeffs (errorstatus, coef, instrument, unit, channels)

Read an ASCII or binary coefficient file and allocate coef structure arrays

Rttov_ErrorReport (errorstatus(inst), errMessage, NameOfRoutine)

Report any errors in reading coeff file

Rttov_dealloc_coef (errorstatus, ierr)

Deallocate the coef structure arrays

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Also supplied

Rttov_writecoef(errorstatus, coef, unit, lbinary)

Write the coefficient coef structure to file in binary or ASCII form according to the logical lbinary.

3.3 RTTOV (Forward Model) main functions

rttov_direct(errorstatus, nfrequencies, nchannels, nbtout, nprof, channels, polarisations, lprofiles, profiles, coef, lcloud, calcemiss, emissivity, transmission, radiance)

Perform the radiative transfer calculations for one coefficient set and nprofiles. Allocates memory for all local structures and de-allocate before return. The same calling structure is used for the TL/AD and K routines. *rttov_direct* calls the following routines:

rttov_checkinput (profile, coef, ierr)

One profile at a time (external loop on profiles) checks the input profile according to the limits given by the coefficient set.

rttov_profaux (profile, coef, aux_prof)

One profile at a time (external loop on profiles) calculates some variables related to input profile, like nearest profile level for surface, or Debye terms (MW only).

rttov_setgeometry (profile, coef, angles)

One profile at a time (external loop on profiles) calculates the auxillary geometry variables according to the input profile.

rttov_setpredictors (profile, angles, coef, predictors)

One profile at a time (external loop on profiles) calculates the RTTOV-7 predictors according to the input profile and geometry.

rttov_setpredictors_8 (profile, angles, coef, predictors)

One profile at a time (external loop on profiles) calculates the RTTOV-8 predictors according to the input profile and geometry.

rttov_transmit (nfrequencies, nchannels, nprofiles, nlevels, channels, polarisations, lprofiles, predictors, aux_prof, coef, transmittances, optical_depth)

Calculates the optical depth and transmittances for the list of channels

rttov_calcemis_ir (profiles, angles, coef, nfrequencies, nprofiles, channels,, lprofiles, calcemiss, emissivity)

Calculation of IR surface emissivity using SSIREM. High resolution radiometers are considered as IR.

rttov_calcemis_mw (profiles, angles, coef, nfrequencies, nchannels, nprofiles, channels, polarisations, lprofiles, surface_transmittance, calcemis, emissivity, reflectivity, errorstatus)

Calculation of MW surface emissivity using FASTEM.

rttov_integrate (addcloud, addcosmic, nfrequencies, nchannels, nbtout, channels, polarisations, lprofiles, emissivity, reflectivity, transmittances, profiles, aux_prof, coef, radiances, aux_rad)

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Integration of the radiative transfer equation for the list of channels according to the profiles, geometry and transmittances.

rttov_calcrad(addcosmic, nchannels, nfrequencies, nprofiles, channels, polarisations, lprofiles, profiles, coef, auxrad%cosmic, auxrad%skin, auxrad%surfair, auxrad%layer)

To calculate layer radiances.

rttov_calcbt(nfrequencies, nchannels, channels, polarisations, coef, radiance)

To compute brightness temperature from radiance.

rttov_calcpolarisation(nfrequencies, nchannels, nprofiles, angles, channels, polarisations, lprofiles, coef, radiance)

To convert an array of brightness temperatures with 1, 2 or 4 polarisations into a single brightness temperature.

rttov_ErrorReport (errorstatus(inst), errMessage, NameOfRoutine)
Report any errors.

3.4 RTTOV_cloud main functions

rttov_cld(errorstatus, nfrequencies, nchannels, nbtout, nprofiles, channels, polarisations, lprofiles, angles, profiles, cld_profiles, coef, calcemiss, emissivity, cld_radiance)

Perform the radiative transfer calculations in cloudy conditions for one coefficient set and nprofiles. Input profiles are given on coefficient pressure levels (profiles) and on NWP pressure levels (cld_profiles). cld_profiles are including a description on pressure levels of cloud cover, cloud liquid water and cloud ice water. Allocates memory for all local structures and de-allocates before return. .
rttov_cld calls the following routines:

rttov_direct(errorstatus, nfrequencies, nchannels, nbtout, nprof, channels, polarisations, lprofiles, profiles, coef, lcloud, calcemiss, emissivity, transmission, radiance)

Perform the radiative transfer calculations for one coefficient set and nprofiles.

rttov_intex(nrt_levels, nwp_levels, nrt_pressures, nwp_pressures, radiance, cld_radiance)

Interpolate the array radiance from the nrt_pressures levels to nwp_pressures levels. Output is stored in cld_radiance.

rttov_emiscld(nfrequencies, nchannels, nprofiles, nwp_levels, channels, polarisations, lprofiles, profiles, coef, cld_profiles, cld_radiance)

To compute cloud emissivity in the micro-wave (0-200 GHz) and in the infrared (50-2860 cm-1) spectral ranges. Inputs are all description of profiles, output is cloud emissivity derived array of cld_radiance.

rttov_aitosu (nfrequencies, nchannels, nprofiles, nwp_levels, polarisations, lprofiles, overlap_scheme, cld_profiles, cld_radiance)

To compute the weights of the black-body-derived radiances. Inputs are description of cloudy profiles, output is the updated cld_radiance derived type.

rttov_calcbt(nfrequencies, nchannels, channels, polarisations, coef, radiance)

To compute brightness temperature from radiance.

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rttov_calcpolarisation(nfrequencies, nchannels, nprofiles, angles, channels, polarisations, lprofiles, coef, radiance)

To convert an array of brightness temperatures with 1, 2 or 4 polarisations into a single brightness temperature.

3.5 RTTOV_scatt main functions

rttov_scatt(errorstatus, nfrequencies, nchannels, nbtout, nprofiles, channels, polarisations, lprofiles, profiles, cld_profiles, coef_rttov, coef_scatt, calcemiss, emissivity, transmission, cld_radiance)

Computes microwave multi-channel radiances and brightness temperatures for many profiles per call in a cloudy and/or rainy sky. *rttov_scatt* calls:

rttov_direct(errorstatus, nfrequencies, nchannels, nbtout, nprof, channels, polarisations, lprofiles, profiles, coef, lcloud, calcemiss, emissivity, transmission, radiance)

Perform the radiative transfer calculations for one coefficient set and nprofiles.

rttov_iniscatt(nfrequencies, nprofiles, nchannels, channels, polarisations, lprofiles, profiles, cld_profiles, coef_rttov, coef_scatt, transmission, angles, scatt_aux, cld_radiance)

Calculates some variables related to the input precipitation profile

rttov_eddington(nfrequencies, nchannels, nprofiles, lprofiles, angles, profiles, cld_profiles, coef_scatt, scat_aux, cld_radiance)

To compute Eddington approximation to RT.

4 RTTOV Tangent Linear (TL), Adjoint (AD) and Jacobian matrix (K) design

The code for TL, AD and K is based on the forward model and has the same calling sequence in the case of the TL code but the reverse sequence for the AD and K codes. All routines for accessing the coefficients or for the error management do not need any TL, AD or K versions. See users guide for a definition of what the TL, AD and K routines actually compute.

5 Forward code modules data-flow

The forward code modules data flow includes the management of the coefficients.

The following schemes are presenting the RTTOV modular design and the data-flow between the modules. Names of the routines are written in brackets. Module inputs are named e_x and outputs are s_x where x is the input/output number. Constrains (input files or main options) are named c_x . Modules are connected by lines which indicates the dependencies and the data-flow.

The first scheme represents the user's level for the forward model, including the access to the coefficients.

The inputs for the module "read coefficients" are the definition of the instrument (platform, instrument, satellite), or a coefficient file already opened, output is a filled coefficient derived type.

The inputs for the module *rttov_direct* are the channels list, profiles and surface emissivity. The constrains are the coefficients, the switch for calculating surface emissivities (*calcemiss*) and the switch for calculating additional cloudy radiances arrays (*addcloud*). The outputs are the transmittances, emissivities and radiances.

The input of the module "deallocation of coefficients" is a coefficient structure and its output is deallocated memory.

Subsequent modules are presented in the same way.

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6 TL/AD/K code modules data-flow

The following schemes are presenting the RTTOVK Matrix modular design and the data-flow between the modules. However they are the same for RTTOVTL and RTTOVAD. Names of the routines are written in brackets. Module inputs are named e_x and outputs are s_x where x is the input/output number. Constrains (input files or main options) are named c_x . Modules are connected by lines which indicates the dependencies and the data-flow.

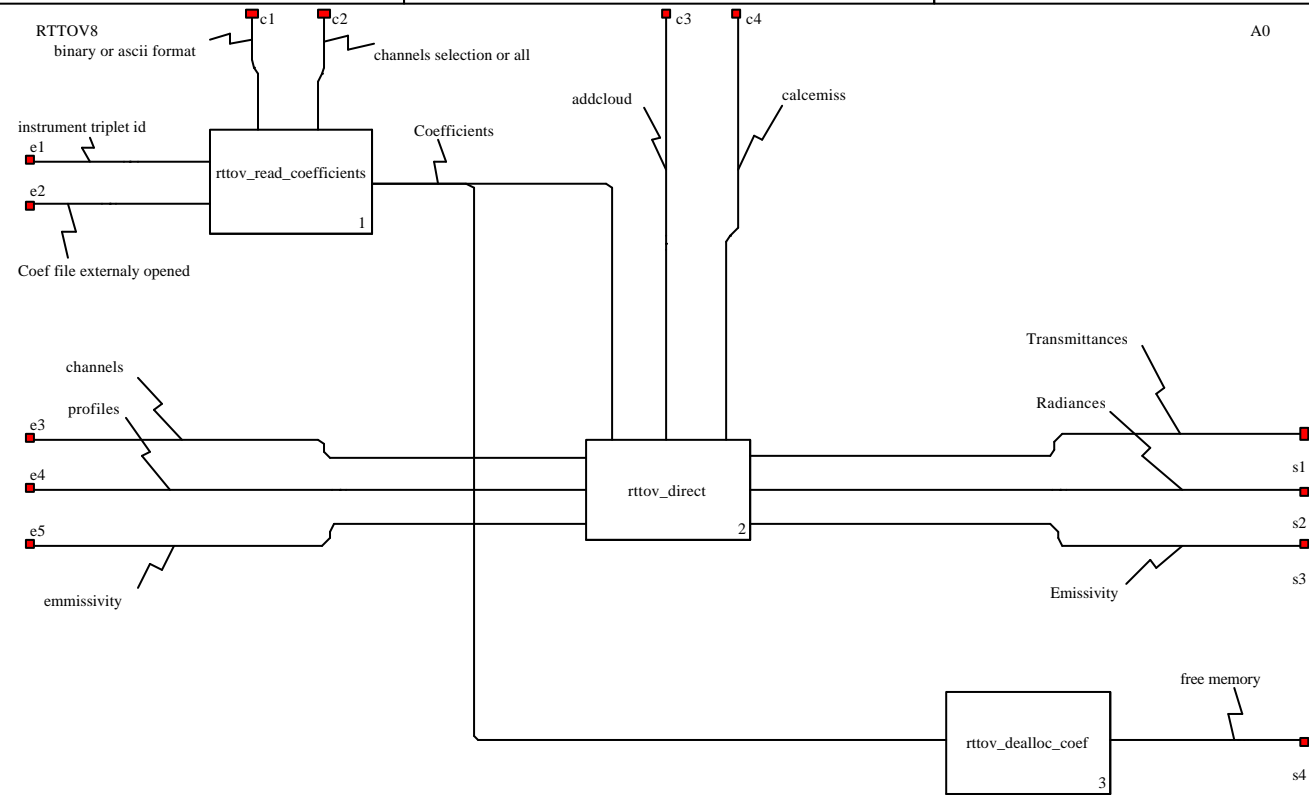
Coefficient management is not reproduced (see forward module)

The first scheme represents the user's level for the K Matrix model. The additional input compared to the forward model is the radiance perturbations and the additional output is the profile and emissivity K matrix.

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 DATE : 11/décembre/2002

LECTEURS :

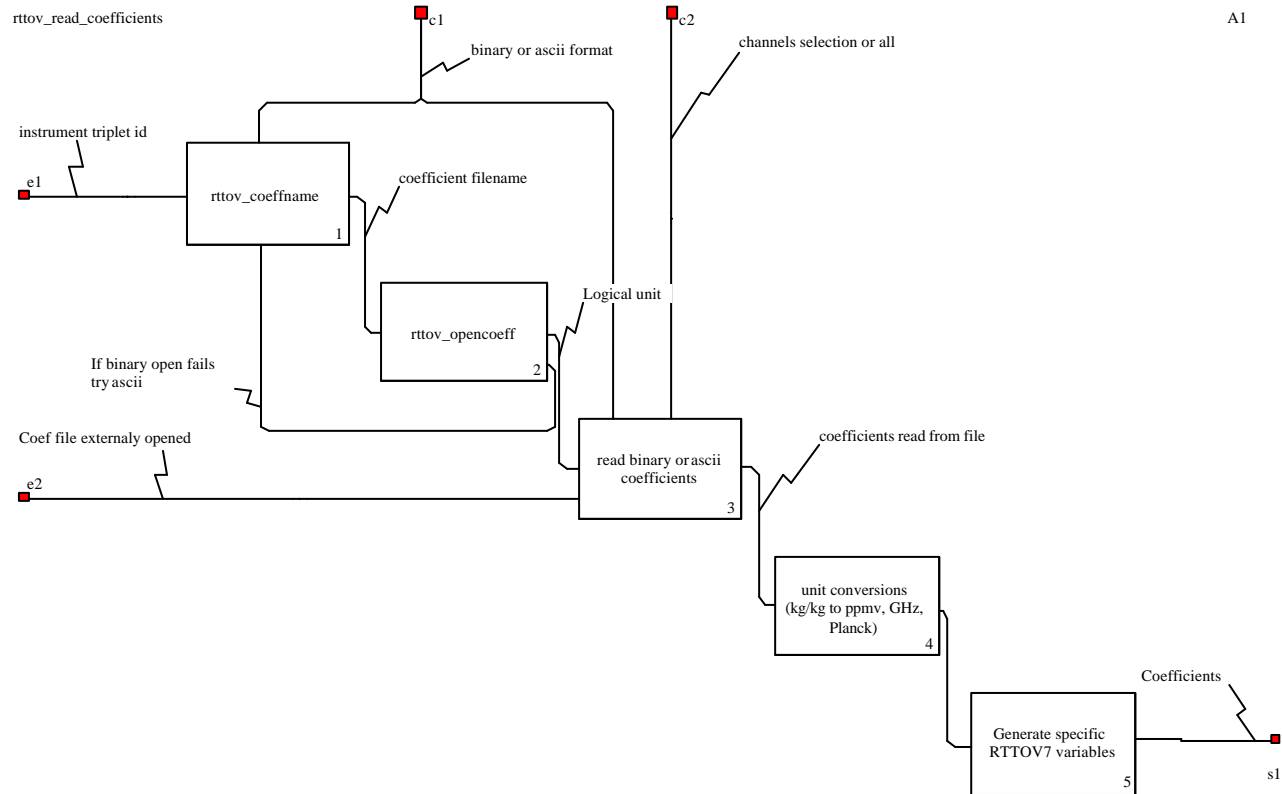
CONTEXTE : NEANT



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LECTEURS :

CONTEXTE : RTTOV8



A1

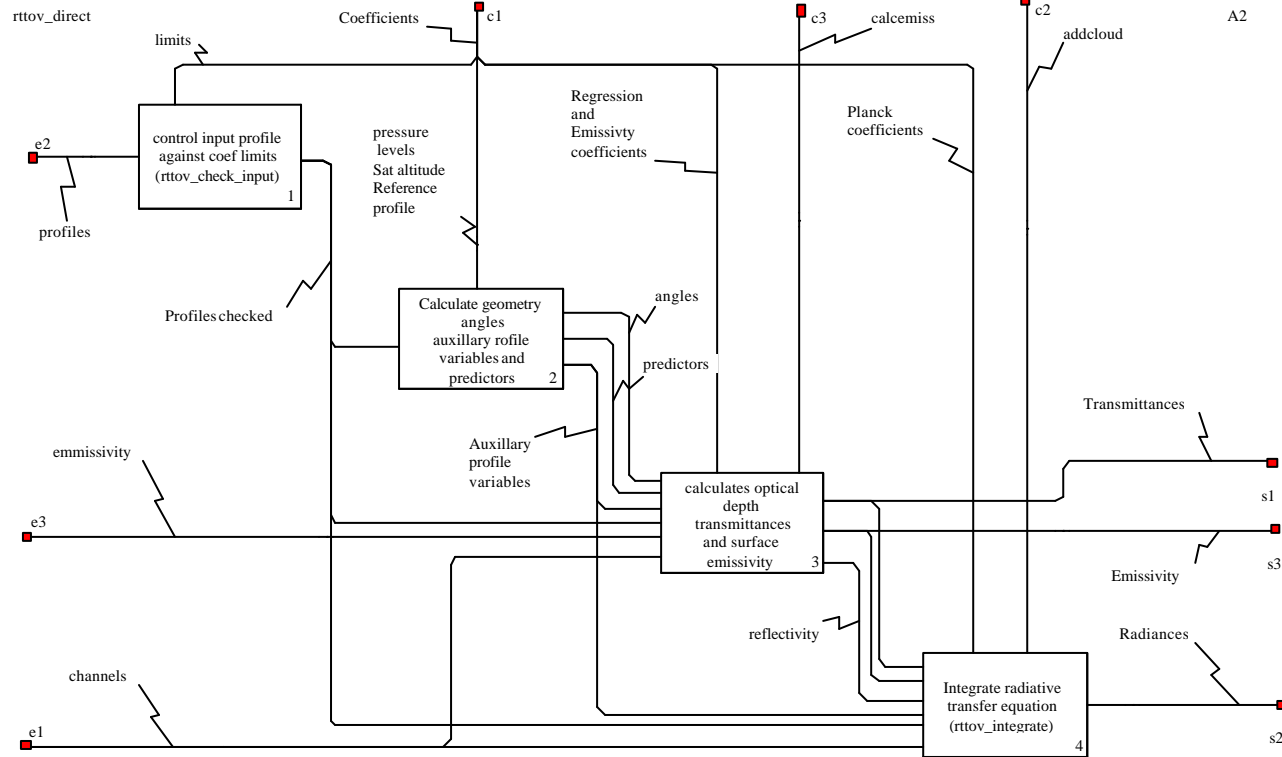
rtov_read_coefficients

VERSION 1.0

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 DATE : 11/décembre/2002

LECTEURS :

CONTEXTE : RTTOV8



A2

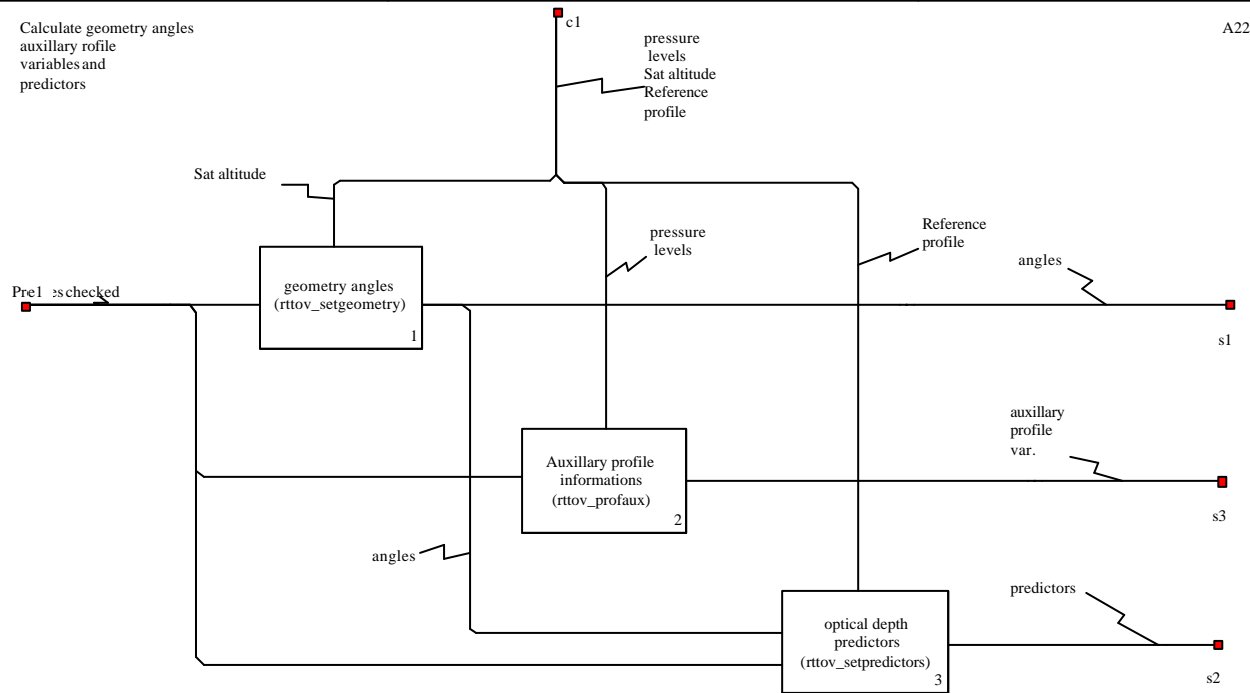
rttov_direct

VERSION 1.0

AUTEUR : P Brunel
 PROJET : RTTOV8 NWP SAF
 DATE : 11/décembre/2002

LECTEURS :

CONTEXTE : rttov_direct



A22

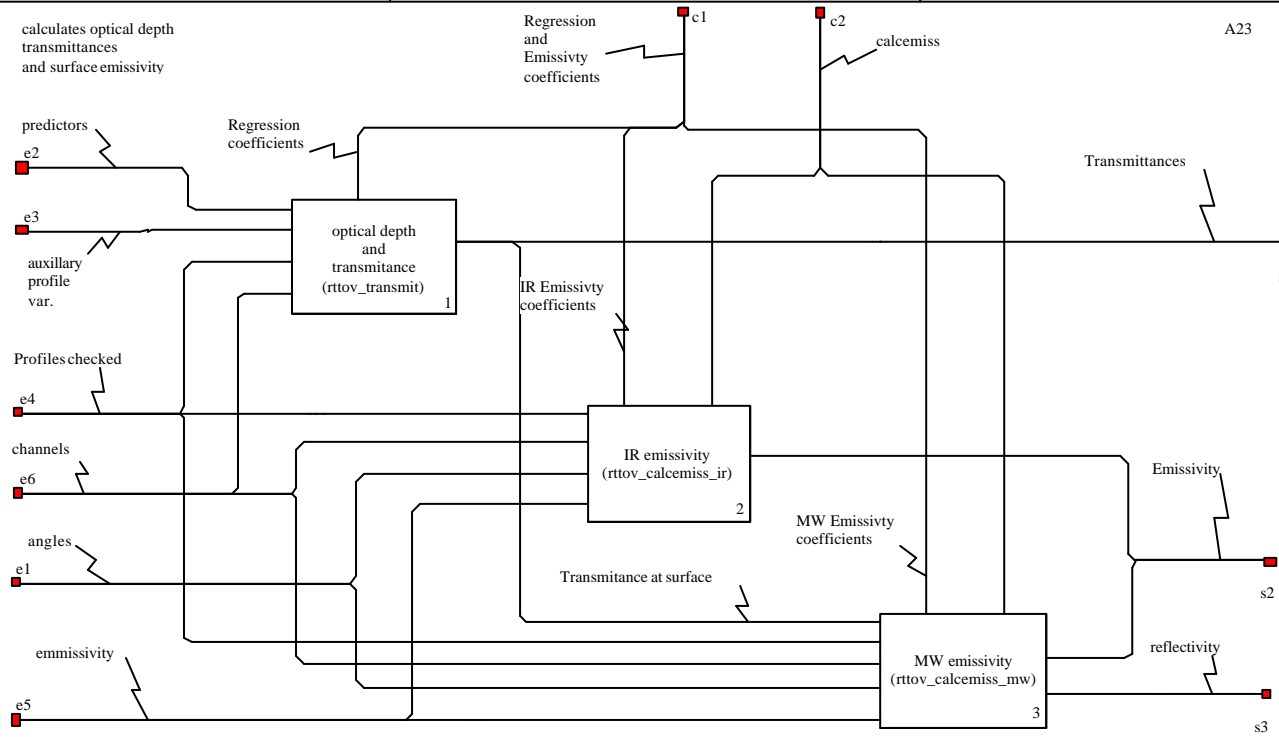
Calculate geometry angles auxillary rofile variables and predictors

VERSION 1.0

AUTEUR : P Brunel
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LECTEURS :

CONTEXTE : rttov_direct



A23

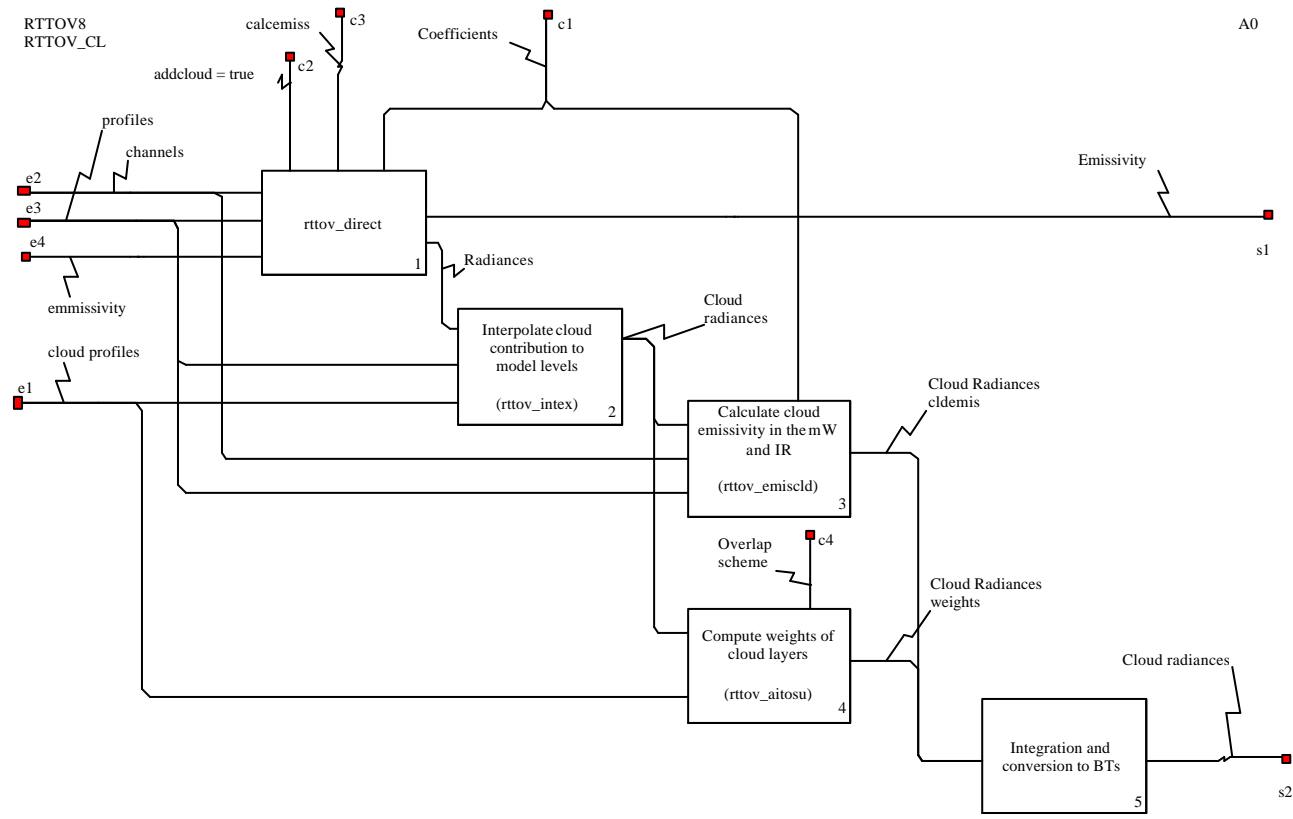
calculates optical depth
 transmittances
 and surface emissivity

VERSION 1.0

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LECTEURS :

CONTEXTE : NEANT



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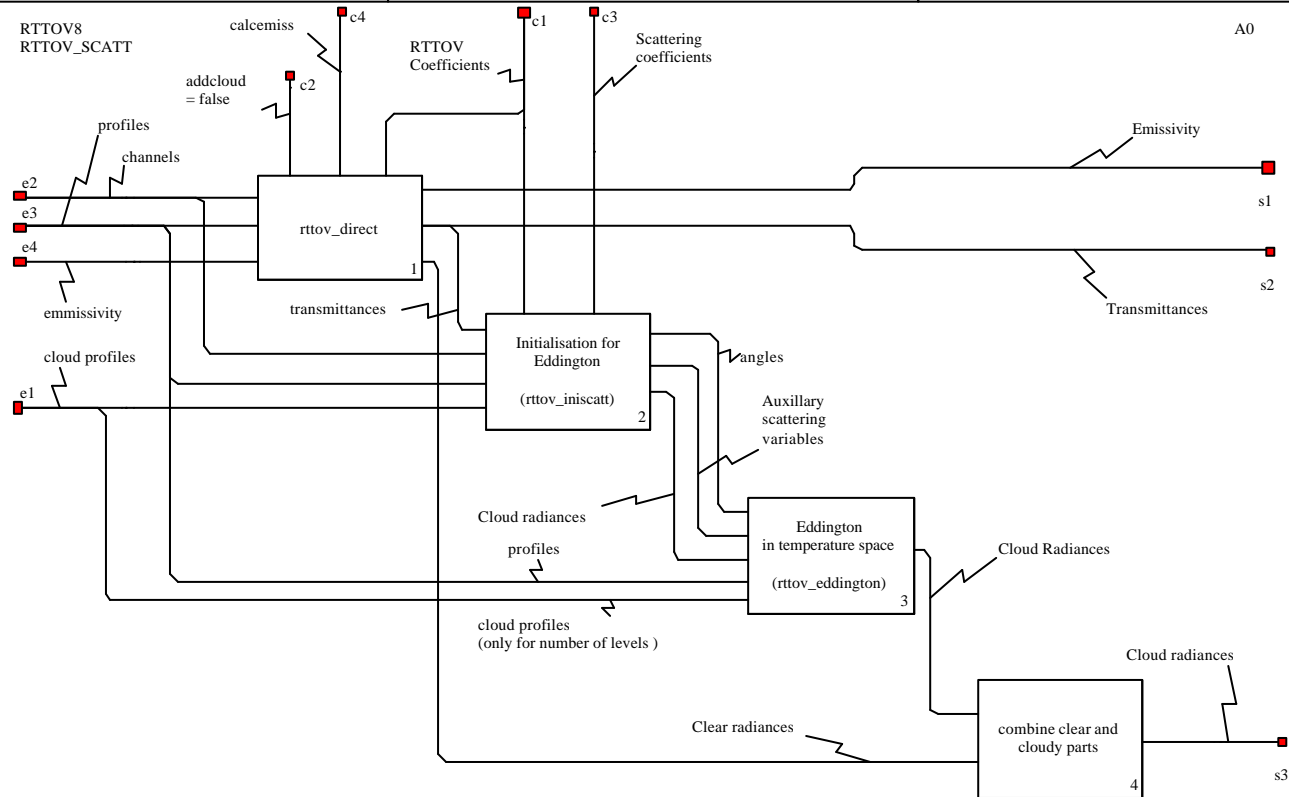
Version : 1.2

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LECTEURS :

CONTEXTE : NEANT



A0

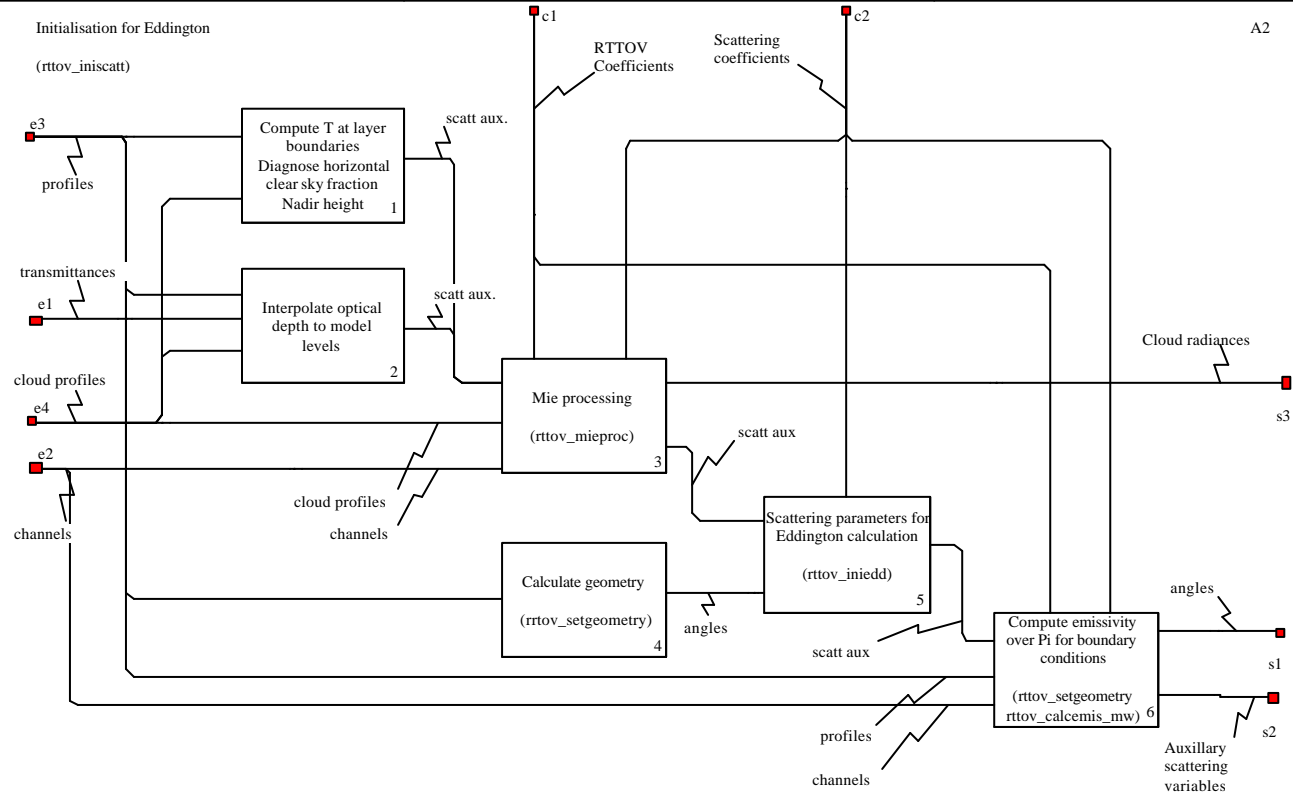
RTTOV8
RTTOV_SCATT

VERSION 1.0

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CONTEXTE : RTTOV8
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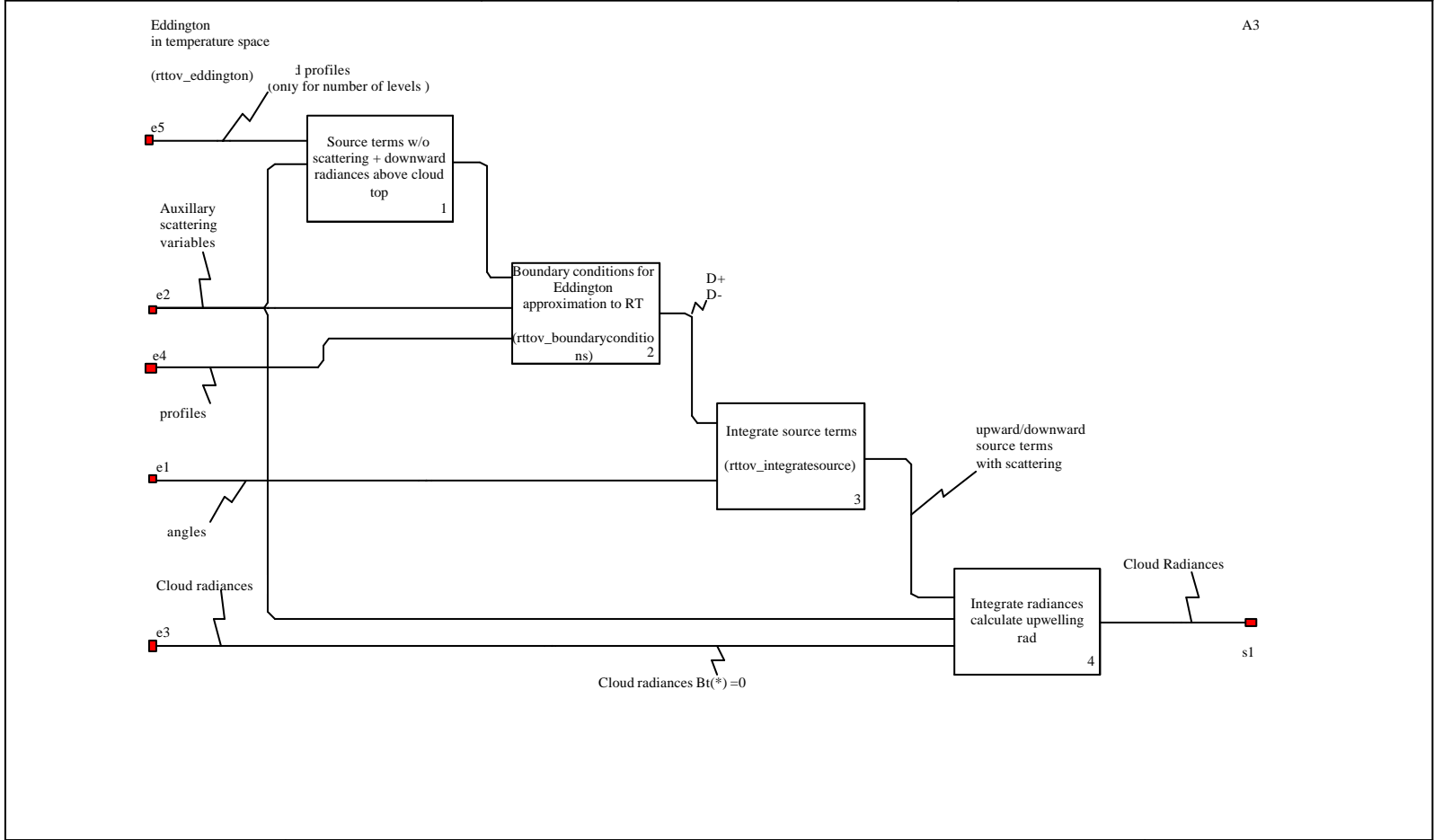
A2

Initialisation for Eddington
 (rttov_iniscatt)

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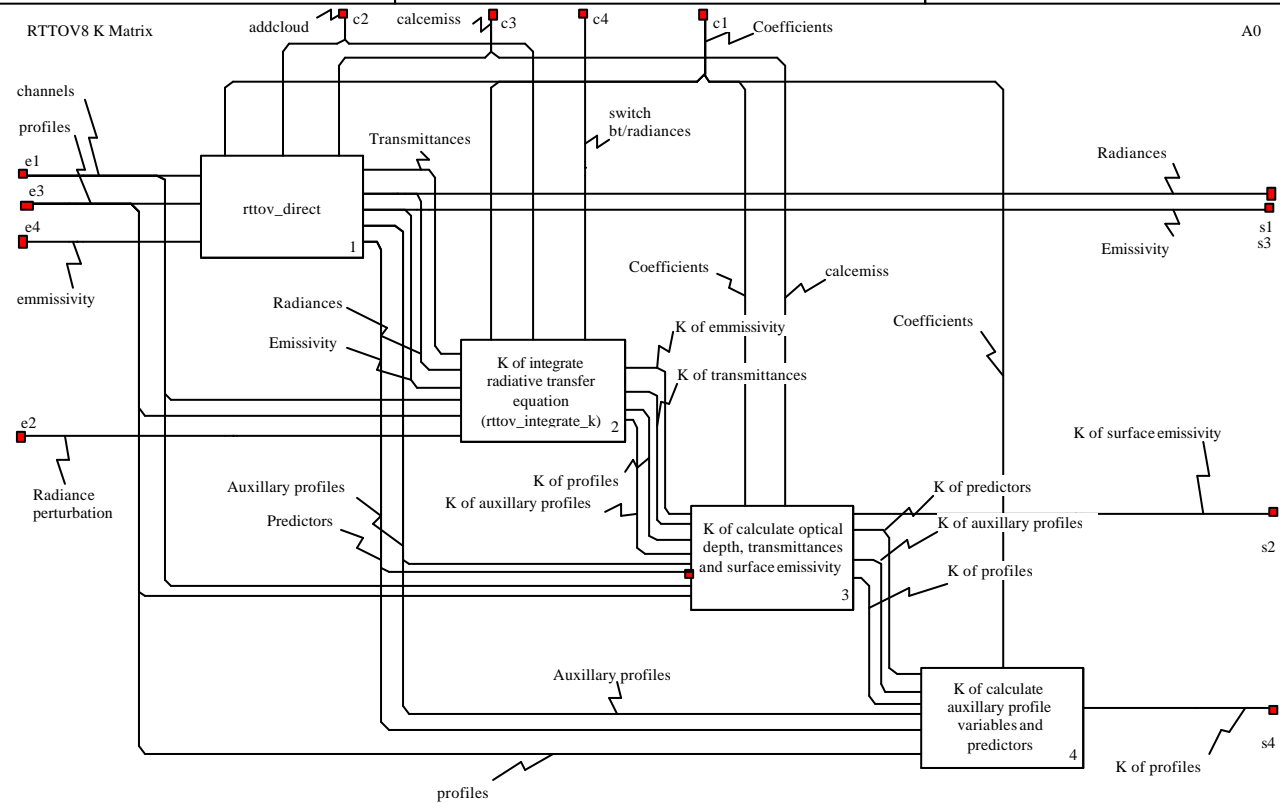
A3	Eddington in temperature space	VERSION 1.0
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(rttov_eddington)

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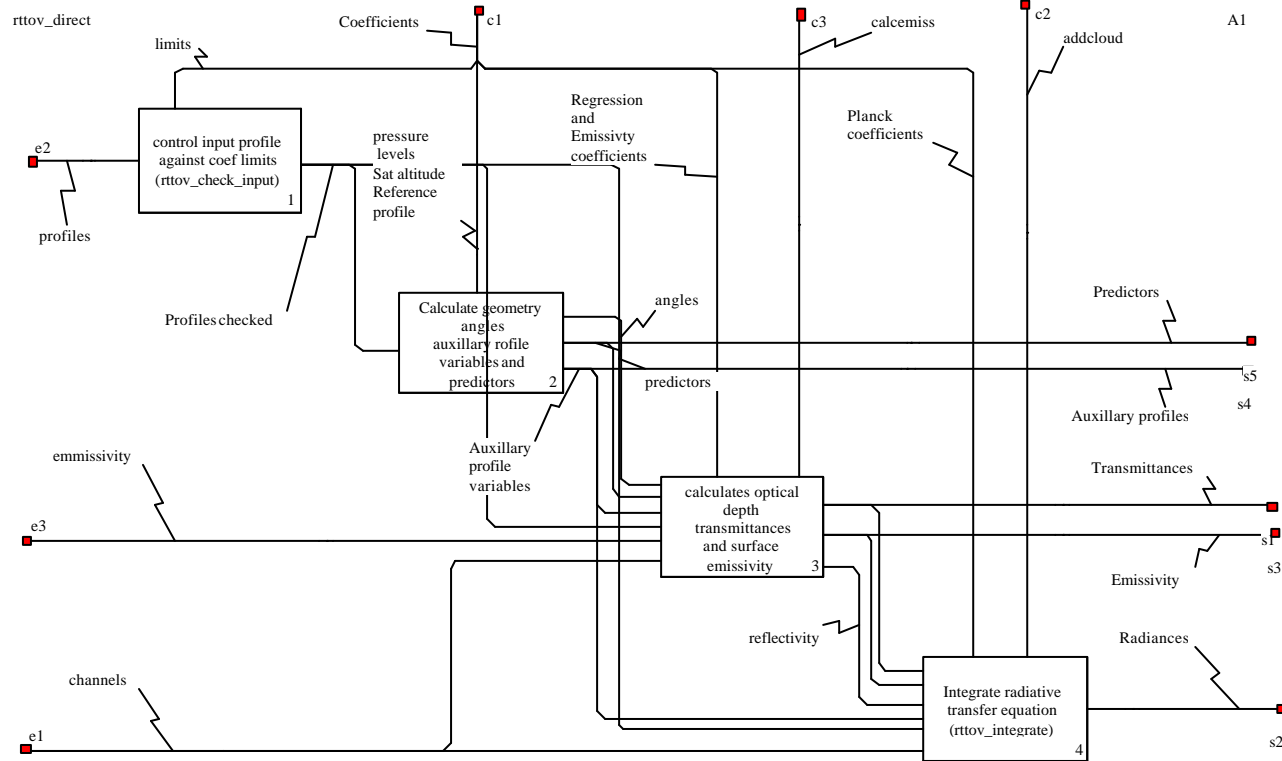
CONTEXTE : NEANT



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CONTEXTE : RTTOV8 K Matrix



A1

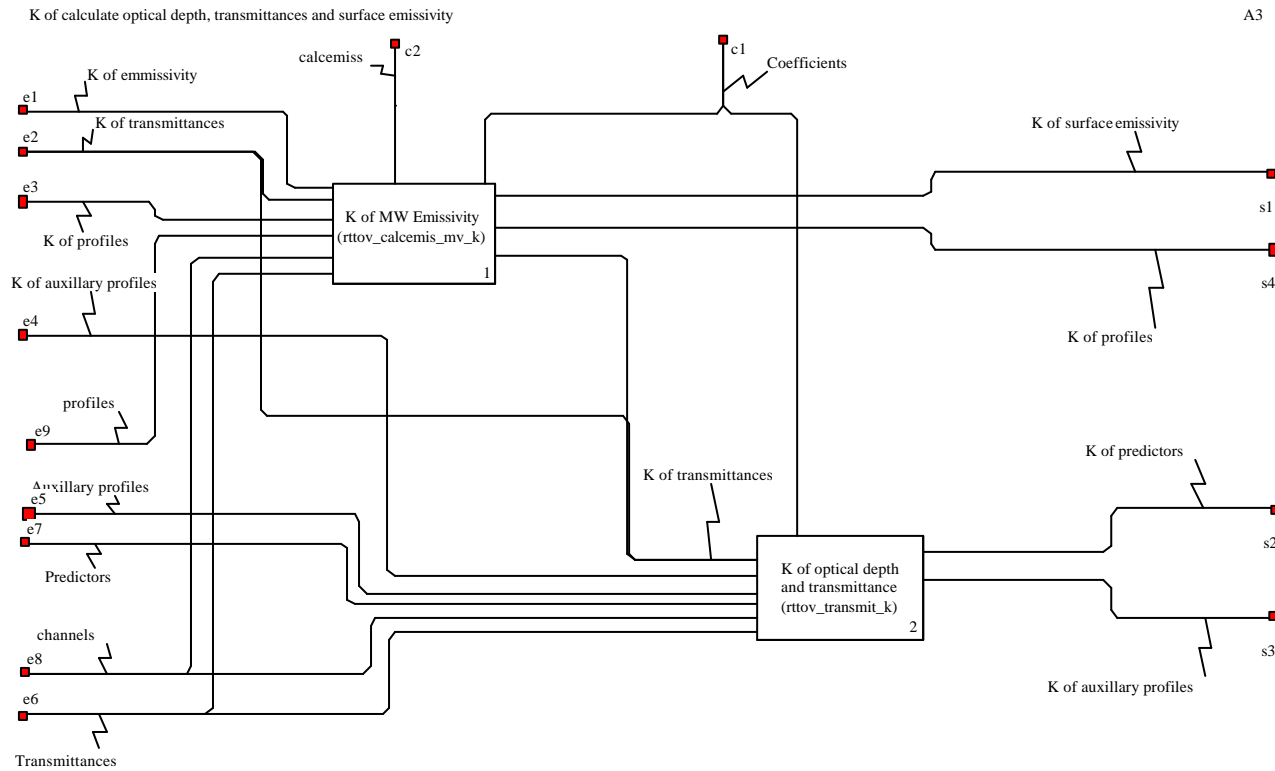
rttov_direct

VERSION 1.0

AUTEUR : P Brunel
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 DATE : 17/décembre/2002

LECTEURS :

CONTEXTE : RTTOV8 K Matrix



A3

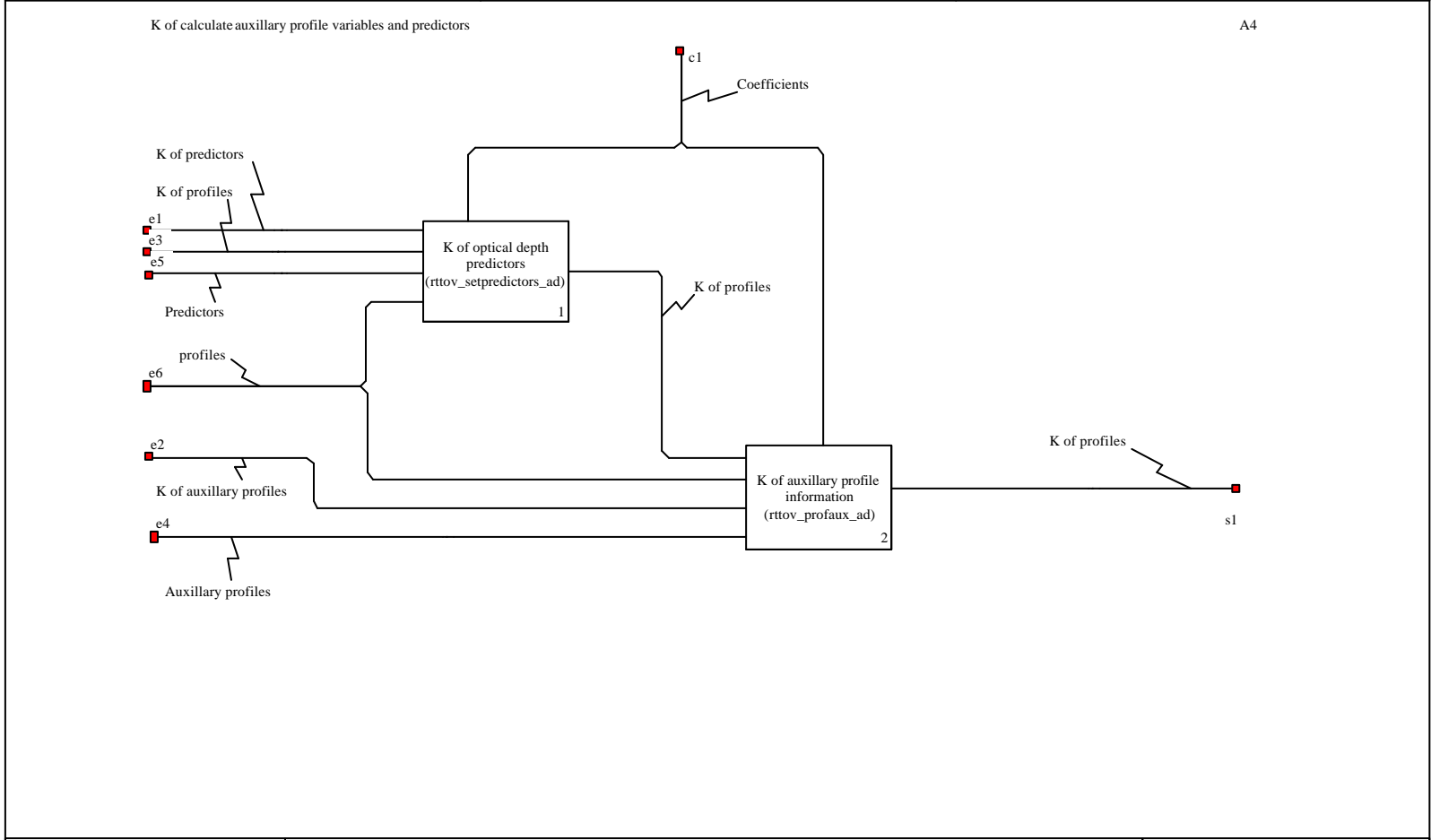
A3

K of calculate optical depth, transmittances and surface emissivity

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A4	K of calculate auxillary profile variables and predictors	VERSION 1.0
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