RTTOV-7 Users Guide

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1	11/12/01	R. Saunders	Initial draft to code developers for comments
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RTTOV-7 Users Guide

1. Introduction and scope

This document gives an overview of the RTTOV-7 fast radiative transfer model (in sec 2), how to install the RTTOV-7 fast radiative transfer model code on a UNIX platform and run it (sec 3) and how to apply it to the users particular problem (sec 4). The procedure for reporting bugs or making comments to the NWP SAF are given in sec 5. Finally a frequently asked questions (FAQ) section is provided at section 6. If you want to order a copy of the RTTOV-7 code send an email to mailto:rttov.nwpsaf@metoffice.com or fax +44-1344-854026 requesting a copy of the code. You will need to sign a RTTOV-7 licence form before the code is sent to you.

The old RTTOV-6 code is still available in FORTRAN-90 or FORTRAN-77 but will no longer be upgraded for new instruments. Note RTTOV-7 is not available in FORTRAN-77. Bugs reported with RTTOV-6 will continue to be announced and users informed of fixes. Coefficient files for RTTOV-6 will continue to be made available from the NWP-SAF web site. The RTTOV-6 code took part in the Garand fast model intercomparison (see Garand et. al. 2001 for details) and has been distributed to over 40 users worldwide.

Before attempting to use the RTTOV-7 model the reader is advised to also read the RTTOV-7 technical report for more details of the code and its operation. The RTTOV-7 scientific and validation report describes or gives links to the scientific basis of the model and also describes in more details any new scientific changes made. It documents the test results carried out on the new code before delivery. The most up to date versions of these reports, like this users guide, can be viewed at the NWP-SAF web site: http://www.metoffice.com/research/interproj/nwpsaf/rtm/ in pdf format on the RTTOV-7 page.

2. Overview of RTTOV-7

This section gives a brief overview of the RTTOV-7 model and its limitations. More details can be found in the references given in this section. RTTOV-7 is a development of the fast radiative transfer model for TOVS, RTTOV, originally developed at ECMWF in the early 90's (Eyre, 1991) for TOVS. Subsequently the original code has gone through several developments (e.g. Saunders et. al., 1999; Matricardi et. al., 2001), more recently within the EUMETSAT NWP Satellite Application Facility (SAF), of which RTTOV-7 is the latest version. The model allows rapid simulations (~1 ms for 40 channel ATOVS on a HP workstation) of radiances for satellite infrared or microwave nadir scanning radiometers given an atmospheric profile of temperature, variable gas concentrations, cloud and surface properties, referred to as the state vector. The only variable gases for RTTOV-7 are water vapour and ozone with all other constituents assumed to be constant. The state vector for RTTOV-7 is given in Table 1. Not all parameters have to be supplied as actual values although sensible defaults need to be supplied as indicated. RTTOV-7 can accept state vectors on any set of pressure levels *but* the coefficients are supplied for the 43 pressure levels defined in Table 2. To work on other pressure levels users would have to supply their own generated coefficients with their own transmittances on these levels.

Currently the spectral range of the RTTOV-7 model is 3-20μm (500 – 3000 cm^{-1}) in the infrared governed by the range of the GENLN2 line-by-line dataset on which it is based. In the microwave the frequency range from 10 – 200 GHz is covered using the Liebe-89 MPM line-by-line model. The full list of currently supported platforms and sensors is given in Table 3, although this list will be updated as new sensors are launched or as improved line-by-line model data are generated. Updated coefficient files will be made available from the RTTOV pages on the NWP SAF web site.

An important feature of the RTTOV model is that it not only computes the forward (or direct) radiative transfer calculation but also the gradient of the radiances with respect to the state vector variables for the input state vector values. Given a state vector **x** a radiance vector **y** is computed:

$$\mathbf{y} = H(\mathbf{x}) \tag{1}$$

where H is the radiative transfer model (also referred to as the observation operator). The Jacobian matrix **H** gives the change in radiance $\boldsymbol{\delta}\mathbf{y}$ for a change in any element of the state vector $\boldsymbol{\delta}\mathbf{x}$ assuming a linear relationship about a given atmospheric state $\mathbf{x_0}$:

$$\boldsymbol{\delta}\mathbf{y} = \mathbf{H}(\mathbf{x}_0)\boldsymbol{\delta}\mathbf{x} \tag{2}$$

The elements of **H** contain the partial derivatives $\partial \mathbf{y_i}/\partial \mathbf{x_j}$ where the subscript i refers to channel number and j to position in state vector. The Jacobian gives the top of atmosphere radiance change for each channel from *each level* in the profile given a unit perturbation at any level of the profile vectors or in any of the surface/cloud parameters. It shows clearly, for a given profile, which levels in the atmosphere are most sensitive to changes in temperature and variable gas concentrations for each channel. *RTTOVK* (and its associated subroutines ending in *K*) compute the $\mathbf{H(x_0)}$ matrix for each input profile.

It is not always necessary to store and access the full Jacobian matrix **H** and so the *RTTOV* package has routines to only output the *tangent linear* values $\boldsymbol{\delta}\mathbf{y}$**,** the change in top of atmosphere radiances, for a given change in atmospheric profile, $\boldsymbol{\delta}\mathbf{x}$**,** about an initial atmospheric state **x**. The tangent linear routines all have *TL* as an ending. Conversely the adjoint routines (ending in *AD*) compute the change in the gradient of any scalar quantity with respect to the atmospheric state, **x,** given a change in the gradient of that quantity with respect to the radiances, **y.** These routines are normally used as part of the variational assimilation of radiances. For users only interested in the forward model the *TL/AD/K* routines are not required.

The model can simulate both clear sky radiances and cloudy radiances. It uses an approximate form of the atmospheric radiative transfer (RT) equation. The top of the atmosphere upwelling radiance, $L(v,\theta)$, at a frequency v and viewing angle θ from zenith at the surface, neglecting scattering effects, is written as:

$$L(v,\theta) = (1-N)L^{Clr}(v,\theta) + NL^{Cld}(v,\theta) \tag{3}$$

where $L^{Clr}(\mathrm{v},\theta)$ and $L^{Cld}(\mathrm{v},\theta)$ are the clear sky and fully cloudy top of atmosphere upwelling radiances and N is the fractional cloud cover.

1.1 Simulation of clear air radiances

If N, the cloud cover parameter (in array PCV), is set to zero and the LWP path profile vector is set to zero (in array PAV(LEV,4,IPROF)) both the infrared and microwave radiances computed are for clear air with the second right hand term of equation 3 being zero. $L^{Clr}(\mathrm{v},\theta)$ can be written as:

$$L^{Clr}(\nu,\theta) = \tau_s(\nu,\theta)\varepsilon_s(\nu,\theta)B(\nu,T_s) + \int_{\tau_s}^{1} B(\nu,T)d\tau + (1-\varepsilon_s(\nu,\theta))\tau_s^2(\nu,\theta)\int_{\tau_s}^{1}\frac{B(\nu,T)}{\tau^2}d\tau \qquad (4)$$

where τ_s is the surface to space transmittance, ε_s is the surface emissivity and $B(v,T)$ is the Planck function for a frequency v and temperature T. The transmittances, τ, are computed by means of a linear regression in optical depth based on variables from the input profile vector as described in Matricardi et. al. (2001). To compute ε_s over water there are fast surface emissivity routines for both the infrared, ISEM, (Sherlock, 1999) and for the microwave, FASTEM-1 (English and Hewison, 1998) or FASTEM-2 (DeBlonde and English, 2001). These models all compute a surface emissivity for the channel of interest at the given viewing angle θ. FASTEM-2 makes a better correction for reflected radiation at the surface. Note that using FASTEM requires the surface wind-speed to be provided in the state vector. Over the land and sea-ice surfaces only approximate default values are provided for the surface emissivity in both the infrared and microwave (see refs above for details and Table 4). The user also has the option of providing their own estimate of surface emissivity to the model if desired (see Table 4 for input options).

1.2 Simulation of cloudy radiances

Assuming black, opaque clouds at a single level the simulation of cloud affected radiances $L^{Cld}(\nu,\theta)$ is defined as:

$$L^{Cld}(\nu,\theta) = \tau_{Cld}(\nu,\theta)\, B(\nu,T_{Cld}) + \int_{\tau_{Cld}}^{1} B(\nu,T)d\tau \qquad (5)$$

where τ_{Cld} (v,θ) is the cloud top to space transmittance and T_{Cld} the cloud top temperature, the emissivity of the cloud top is assumed to be unity which is a tolerable assumption for optically thick water cloud at infrared radiances but not valid for optically thin cloud and all cloud at microwave frequencies.

For microwave frequencies the liquid water profile can be supplied in array *PAV(1:LEV,4,IPROF)* as cloud liquid water concentration in units of kg/kg. Only layers from the surface to the level *jmwcldtop* set in the *MOD_CPARAM.f90* file (see below) are taken into account in the computation. The default value set is for a level at 321 hPa. For cloud water drops scattering is assumed to be negligible below 200 GHz and so it follows that the extinction per unit mass is independent of radius and thus the sensitivity of changes in optical depth to changes in liquid water mass is independent of the drop-size distribution. This allows a calculation of the optical depth if an assumed dependence of the permittivity of the liquid water with temperature is assumed. Ice extinction is assumed to be zero so the input cloud water profile is all assumed to be liquid. Scattering becomes important for ice crystals above 100GHz. If the liquid water concentration value at the top level of 0.1hPa is set to negative the liquid water path transmittance calculation is not performed regardless of the input profile which reduces execution time of the model.

For the standard RTTOV model at infrared frequencies clouds are assumed to be at one level, have unit emissivity and a top at a fixed cloud top pressure with a fractional coverage for each input profile. The outputs of *RTTOV* can be used however to simulate a more realistic multilevel infrared and microwave cloudy radiance and the *RTTOVCLD* routines now supplied with RTTOV-7 provide this capability. *RTTOVCLD* and its associated TL/K/AD routines take a profile input on 43 levels for the normal state variables in Table 1 and the gaseous transmittances are computed on the 43 levels. In addition *RTTOVCLD* also takes a profile of temperature, cloud cover, cloud liquid water (kg/kg) and cloud ice water (kg/kg) on user defined model pressure levels and computes infrared and/or cloudy radiances for multilevel and multiphase cloud fields. The clear and cloudy radiative transfer computation is done on the user defined model levels in *RTTOVCLD*. The advantage of using this method for computing cloudy microwave radiances is there is no interpolation to the RTTOV levels for the cloudy radiance computations and there is a consistent random-overlap scheme with the infrared. More details are given in Chevallier *et. al*.(2001) and the RTTOV-7 science and validation plan for this enhancement of *RTTOV*.

2.3 Current limitations of RTTOV-7

There are a number of limitations of RTTOV-7 the user should be aware of. Some are fundamental and some are not. The main ones are listed here:

- RTTOV-7 only simulates top of atmosphere radiances from a nadir or off-nadir view which intersects with the Earth's surface (i.e. no limb paths).
- RTTOV-7 does not include any reflected solar component.
- RTTOV-7 does not include scattering effects.
- RTTOV-7 only allows for water vapour and ozone to be variable gases with all others included in the mixed gases transmittance calculation.
- RTTOV-7 does not simulate IASI or CRIS radiances. Other lower resolution IR or MW sensors can be simulated *if* their filter responses are known.
- RTTOV-7 as supplied can only provide simulations with a 43 level profile as input on the defined pressure levels in Table 2. However if users have an alternate dependent set of LbL transmittances on different levels they can compute a new coefficient set on these levels.
- The accuracy of simulations for very broad channels (e.g. SEVIRI channel 4 at 3.9 microns) is poor with significant biases noted (~1-2K). This is the case for all versions of RTTOV.
- RTTOV-7 does not include the variation of the zeeman effect with magnetic field strength for the high peaking AMSU-A and SSMIS channels. Only a constant correction factor is included.

3. FORTRAN-90 UNIX installation

Some basic information on installing the RTTOV-7 Fortran 90 code in a UNIX environment follows. This assumes the code is obtained as a compressed unix tar file via ftp or on CD-ROM from ECMWF. The file name should be *rttov7.tar.Z* and be copied to your 'top' RTTOV directory (e.g. *~user/rttov7*) from which subdirectories will be created. Text in *italics* refers to specific commands to execute during the installation or file names.

3.1 Unpacking the code

First uncompress the tar file:
uncompress rttov7.tar.Z

and expand it:
tar -xvf rttov7.tar

The following subdirectories are created and contain:
- *src* Fortran source code + make files for a variety of platforms
- *scripts* Unix test scripts for running test programs
- *data* Associated input data files required for testing
- *rtcoef* RT coefficient files for all sensors supported
- *test* Output of test programs run on user's machine
- *reftest* Output of test programs run by NWP SAF

- *docs* Documentation

3.2 Compiling the code

First go to the source code directory:
cd src

The fortran code consists of subroutines and modules and 3 top level test programs (*TSTRAD.f90, MAIN_TESTAD.f90, MAIN_TESTK.f90)* in *src* for complete testing of the RTTOV and RTTOVCLD subroutines. The first step is to compile the code and make an executable using the makefiles supplied. Edit the file called *Makefile* in *src* so that the f90 compiler options match those available on your machine. A selection of compiler flags for different platforms are listed so if you are running using one of these compilers you should be able to just uncomment the relevant section. Once this is done type *make* and with luck the code will compile and produce an executable *tstrad.out* for the RTTOV tests, *main_testad.out* and *main_testk.out* for the RTTOVCLD tests. The Makefile should copy these three executable files to the *scripts* subdirectory.

If the compilation was not successful then either edit the makefile again until it does or if all else fails compile the code manually as follows. Note you must first compile the modules then the subroutines and program:
Step 1: *f90 –c –your flags MOD_*.f90*
Step 2: *f90 –c –your flags *.f90*
Step 3: *rm -f main_test*.o* (to ensure the clear air test code *tstrad* compiles)
Step 4: *f90 *.o*

This should produce an executable file *a.out* in your *src* directory which you should then move to your *scripts* directory renamed as *tstrad.out.* This only provides code to test the RTTOV routines and not the RTTOVCLD routines (above RTTOV). If you want to test the cloudy routines also restart from step 3 and *rm -f tstrad.o* and recompile *main_testad.f90.*

3.3 Running the code

There are test scripts for running the executables (*tstrad.out* etc) which must be in the *scripts* directory. The controlling script is *tstrad_all.scr*. This script calls the other scripts in sequence to test RTTOV for clear air, cloudy air and all instruments and in both forward model test mode and using *tstrad_full.scr* to fully test the TL/AD/K routines. If you only want to use the code in forward mode and/or for 1 instrument or clear air you may wish to reduce the number of test scripts called in *tstrad_all.scr* to just test for your particular application by commenting out calls to some of the scripts.

The rt coefficient files (for all instruments supported as listed in Table 3) and input files for running *tstrad.out* the test program are all in the subdirectories *rtcoef* and *data* respectively. Output files from the runs on the NWPSAF machine at the Met Office are given in *reftest.* The files in *reftest* can be compared with the output produced locally (the scripts write the output to a subdirectory *test* as **.lst* files) and difference files from those in *reftest* are also created *as *.diff* files in the *test* subdirectory. To check the installation has been successful you should check the **.diff* files are all of size zero. Note however the TL/AD/K test outputs will differ slightly due to machine precision differences and use of a random number generator in the test code and so typical differences between machines are shown in the listing in Table 5. These differences are normal. Once the code does reproduce the results in the sample files the code can then be linked into the users own particular applications. The subroutine interfaces and file structures are described in detail in the annexes and the RTTOV-7 technical report.

4. Running RTTOV-7 for your applications

To run RTTOV-7 for a user's application the program *tstrad.f90* can be used as a rough guide or template. There are only 2 subroutines that must be called: *RTTVI* to initialise the arrays and read in the coefficients requested and secondly the call to *RTTOV* itself which actually computes the radiances. Users requiring the TL/AD/K routines may also call *RTTOVTL/RTTOVAD/RTTOVK* as required. It is recommended that users look at the header section of the coefficient file for the sensor they wish to simulate as there is useful information such as the definition of channel number for that instrument etc. The following steps are recommended in coding a program which calls RTTOV.

1. Include the module *MOD_CPARAM.f90* in your program (see tstrad.f90 as an example).
2. Edit *MOD_CPARAM.f90* for your application to minimise the array sizes. This will normally consist of setting the channel number parameters *JPCH* and *JPCHUS* to the maximum number of channels you require computations for in one call to *RTTOV*. Secondly setting the number of profiles parameter *JPPF* to the maximum number of profiles you want to compute in one call to *RTTOV* (this is normally set to 1 as there is only a significant advantage to process many profiles per call on vector machines). Thirdly *JPNSAT* should be set to the maximum number of sensors simulated in the program (e.g. for ATOVS only it would be 3, HIRS, AMSU-A and AMSU-B) . *JPLEV* should be set to the number of levels assumed in the coefficient file which is currently 43 for the files distributed with the code. All other parameters are normally left unchanged. See RTTOV technical report for listing of parameters.
3. Initialise the variables input to *RTTVI* and *RTTOV* in your code. These are defined in Annexes A and B. In particular you need to fill the state vector arrays listed in Table 1 with the values in the correct units and on the 43 pressure levels. This may require an interpolation step from your original profile levels.[1] The channel number array *KCHAN* must be filled with the required channel numbers (see rt_coef files for their definition) and the satellite zenith angle array with the required satellite zenith angle(s) (in deg). The latter is the angle from the zenith at which an observer on the surface observes the satellite. <u>It is not the nadir scan angle.</u> If you are simulating more than one sensor in each run then the order in which you load up the coefficient files of the sensors in RTTVI becomes important (i.e. the order of values in the *PLATFORM*, *SATELLITE* and *INSTRUMENT* id arrays). The *KSAT* index number used in *RTTOV* then refers to the order they are loaded in RTTVI (e.g. KSAT=1 refers to the first sensor, KSAT=2 to the second and so on).
4. Compile the RTTOV modules first followed by the RTTOV subroutines followed by your main calling program (see makefile supplied). You do not have to compile in double precision (-r8 flag on some compilers) as this is only used in the test programs supplied to ensure there is enough precision to check the code is giving the correct answers.
5. Make sure the coefficient file for the instrument you want to simulate is in the same directory as the executable (or a symbolic link to the file is made).
6. You should now be able to run the program to compute radiances. It is wise to check the IFAIL flag from RTTOV to check it is zero. If it is non-zero there are a number of possible reasons according to the number returned (see Table 6).

1 It is planned to make available some standard code to do this interpolation robustly in the near future.

7. Note that if you set the *PEMIS* array to zero on input, to call the internal surface emissivity routines ISEM or FASTEM, then on output the array contains the computed emissivities for each channel. Before calling *RTTOV* again you must reinitialise the array to zero.
8. The *RTTOVTL/RTTOVAD/RTTOVK* routines are called in the same way as RTTOV (see annexes C-E). Again ensure all arrays are initialised before calling the routines.
9. The *RTTOVCLD* routines are a level up from *RTTOV* but they have almost the same calling structure and arrays to fill. Again the test program supplied *main_testad.f90* can be used as an example. Note however the cloud parameter arrays are input on user defined model levels. More details on the *RTTOVCLD* routines are planned for the next version of this user manual.

5. Reporting bugs to the NWP SAF

The procedure to report bugs or make comments on the code to the NWP-SAF is as follows:

Send a bug report to rttov.nwpsaf@metoffice.com including the following information:

- RTTOV version number (i.e. 5, 6 or 7)
- Platform and operating system you are running the code on (e.g. HP, UNIX)
- Compiler used (e.g. HP FORTRAN-90)
- Classification of report as: serious, cosmetic or improvement
- Copy of file MOD_CPARAM.f90 (for RTTOV-7) or cparam.h (for RTTOV-5/6)
- Report of problem including any input / output files the SAF can use to reproduce the problem

Once the problem has been analysed it will be posted on the RTTOV web site with a description of the fix if appropriate. There is also a RTTOV email list which you can subscribe to by sending an email to mailto:rttov.nwpsaf@metoffice.com where bugs are announced.

6. Frequently asked questions

This section will be updated on the web pages from time to time.

1. Can I compile the code in single precision? *Yes the Makefiles supplied only compile the code in double precision for the purposes of testing.*

2. I don't have an ozone profile to include in the state vector. What can I do? *You should fill the input state vector PAV(lev,3,prof) with the reference ozone profile (units kg/kg) listed in the right hand column of Table 2 for all values of lev and repeated for each profile stored in PAV.*

3. I am only simulating radiances from 1 instrument what should *KSAT* be set to? *Set KSAT to 1 as it is the first and only instrument coefficient files loaded by RTTVI.*

4. Why do the numbers in the TSTRAD output (see Table 5) change from run to run? *A random number generator is included in the code so different values can be expected. The important thing is SUMPROF=SUMRAD to machine precision.*

5. More to be added here……please make suggestions!

Good Luck and please provide me with any feedback on your experiences. Remember do not pass this code on to anyone else without the permission of EUMETSAT. The code is provided to you on an "as is" basis and there is no commitment to maintain it.

6. References

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Sherlock, V. 1999 ISEM-6: Infrared Surface Emissivity Model for RTTOV-6. NWP SAF report (available from the librarian at Met Office, London Rd Bracknell, U.K.)

Position in vector PAV	Profile Array Contents	Units
1 to NLEV/1	Temperature profile	degK
1 to NLEV/2	Water vapour profile	Kg/Kg
1 to NLEV/3	Ozone profile ‡	Kg/Kg
1 to NLEV/4	Liquid water concentration profile †	Kg/Kg
Position in vector PSAV	Surface 2m Array Contents	Units
1	Surface 2m temperature	degK
2	Surface 2m water vapour	Kg/Kg
3	Surface pressure	hPa
4	2 m vector wind speed u #	$m.s^{-1}$
5	2 m vector wind speed v #	$m.s^{-1}$
Position in vector PSSV	Surface Skin Array Contents	Units
1	Radiative skin temperature	degK
2	FASTEM-2 land coef ε_s ¶	
3	FASTEM-2 land coef ε_∞ ¶	
4	FASTEM-2 land coef ν_r ¶	GHz
5	FASTEM-2 land coef σ_{small} ¶	mm
6	FASTEM-2 land coef σ_{large} (or Q) ¶	mm
Position in vector PCV	Cloud Array Contents	Units
1	Cloud top pressure (ignored if cloud cover is zero. Set to 500 as default)	hPa
2	Cloud fractional cover (set to 0 for clear sky 1 for 100% cloud cover)	0-1
Position in vector PEMIS	Surface Emissivity Array Contents	Units
1 to NCHAN	Surface emissivity (if set to zero or -1. provide default value as defined in Table 4)	0-1

‡ If unavailable initialise to reference ozone profile listed in any rt_coef file and ozone will be assumed constant.

† This variable only affects microwave cloudy radiance simulations, default set to zero and set top level to –0.1 to switch off transmittance computation to save time if not required. IR and MW cloudy radiances also governed by PCV vector.

#Only used by FASTEM-1/2 to compute microwave sea surface emissivity. If not required set to zero.

¶ See Table 1 of English and Hewison (1998) or Table 3 of RTTOV-7 science and validation report for typical values for different surface types. Set to zero if not required.

Table 1. State vector for RTTOV-7 model. NLEV is the number of profile levels (currently 43) and NCHAN the number of channels. Default values are also given where appropriate.

Level number	Pressure (hPa)	Tmax deg K	Tmin degK	Qmax Kg/Kg	Qmin Kg/Kg	O_3max Kg/Kg	O_3min Kg/Kg	O_3 Ref Kg/Kg
1	0.1	335.5	162.0	4.38E-05	1.20E-06	1.63E-05	7.00E-07	9.69E-06
2	0.3	335.8	173.1	4.65E-05	1.20E-06	1.69E-05	1.00E-06	1.00E-05
3	0.7	352.8	168.9	4.61E-05	1.20E-06	1.70E-05	2.10E-06	1.01E-05
4	1.4	354.4	160.9	4.51E-05	1.20E-06	1.71E-05	2.11E-06	1.02E-05
5	2.6	349.4	160.5	4.29E-05	1.20E-06	1.71E-05	2.11E-06	1.02E-05
6	4.4	328.8	160.3	4.26E-05	1.20E-06	1.71E-05	2.11E-06	1.02E-05
7	7.0	321.4	158.5	4.36E-05	1.20E-06	1.71E-05	2.11E-06	1.02E-05
8	10.4	300.3	154.7	4.35E-05	1.20E-06	1.71E-05	2.11E-06	1.02E-05
9	14.8	295.0	154.9	4.01E-05	1.20E-06	1.72E-05	2.11E-06	1.01E-05
10	20.4	289.0	151.1	4.03E-05	1.20E-06	1.61E-05	2.11E-06	9.36E-06
11	27.3	286.5	151.2	4.18E-05	1.20E-06	1.60E-05	2.03E-06	8.10E-06
12	35.5	285.3	151.6	3.62E-05	1.20E-06	1.14E-05	8.33E-07	6.72E-06
13	45.3	284.2	152.5	3.43E-05	1.20E-06	1.11E-05	5.49E-07	5.19E-06
14	56.7	283.8	154.2	3.33E-05	1.20E-06	9.82E-06	2.85E-07	3.72E-06
15	70.0	282.7	155.7	3.23E-05	1.20E-06	6.46E-06	2.13E-07	2.58E-06
16	85.2	282.7	153.9	3.01E-05	1.20E-06	5.31E-06	1.71E-07	1.72E-06
17	102.1	281.5	151.5	2.90E-05	1.20E-06	4.10E-06	6.96E-08	1.19E-06
18	122.0	280.1	156.7	3.58E-05	1.20E-06	3.63E-06	1.18E-08	8.45E-07
19	143.8	278.6	157.4	8.61E-05	1.20E-06	3.06E-06	1.03E-08	6.50E-07
20	168.0	278.8	159.7	1.64E-03	1.20E-06	2.24E-06	8.72E-09	5.27E-07
21	194.4	280.1	163.2	2.79E-03	1.20E-06	1.64E-06	7.43E-09	4.13E-07
22	222.9	282.3	165.3	4.44E-03	1.20E-06	1.47E-06	7.14E-09	3.03E-07
23	253.7	285.3	166.7	7.64E-03	1.20E-06	1.09E-06	1.20E-08	2.11E-07
24	286.6	288.7	167.6	1.12E-02	1.20E-06	7.60E-07	1.16E-08	1.56E-07
25	321.5	294.0	170.6	1.68E-02	1.20E-06	5.90E-07	1.59E-08	1.23E-07
26	358.3	300.5	174.2	2.54E-02	1.20E-06	3.83E-07	7.94E-09	1.08E-07
27	396.8	306.4	175.3	3.62E-02	1.20E-06	3.13E-07	1.13E-08	1.01E-07
28	437.0	312.2	178.8	5.00E-02	1.20E-06	2.45E-07	6.58E-09	9.60E-08
29	478.5	317.2	182.1	6.50E-02	1.95E-06	2.34E-07	6.24E-09	9.17E-08
30	521.5	321.1	185.0	7.75E-02	4.51E-06	2.31E-07	4.95E-09	8.91E-08
31	565.5	325.2	187.8	8.95E-02	1.04E-05	2.13E-07	2.76E-09	8.47E-08
32	610.6	328.2	190.3	1.05E-01	1.29E-05	2.01E-07	2.41E-09	8.12E-08
33	656.4	333.0	192.8	1.24E-01	1.42E-05	2.07E-07	2.27E-09	7.78E-08
34	702.7	336.8	195.4	1.41E-01	1.71E-05	2.21E-07	2.07E-09	7.57E-08
35	749.1	340.7	197.1	1.59E-01	3.63E-05	1.87E-07	7.24E-10	7.12E-08
36	795.1	344.4	198.4	1.78E-01	5.34E-05	1.91E-07	7.24E-10	6.63E-08
37	840.0	348.0	199.0	2.00E-01	6.42E-05	1.81E-07	7.24E-10	6.16E-08
38	882.8	350.3	197.5	2.14E-01	6.68E-05	1.73E-07	8.10E-10	5.68E-08
39	922.5	352.2	195.5	2.40E-01	6.57E-05	1.68E-07	8.10E-10	5.21E-08
40	957.4	354.7	188.2	2.70E-01	6.57E-05	1.65E-07	8.10E-10	4.79E-08
41	985.9	356.6	155.0	2.79E-01	6.57E-05	1.63E-07	8.10E-10	4.44E-08
42	1005.4	357.9	135.0	2.82E-01	6.57E-05	1.62E-07	8.10E-10	4.20E-08
43	1013.3	385.9	135.0	2.84E-01	6.57E-05	1.62E-07	8.10E-10	4.10E-08

Table 2 Pressure levels adopted for RTTOV-7 and the profile limits within which the transmittance calculations are valid. The default ozone profile is also given in the right hand column.

Platform	RTTOV id	Sat id range
NOAA	1	1 to 16
DMSP	2	8 to 16
Meteosat	3	5 to 7
GOES	4	8 to 12
GMS	5	5
FY-2	6	2
TRMM	7	1
ERS	8	1 to 2
EOS	9	1 to 2
ENVISAT	11	1
MSG	12	1
FY-1	13	3 to 4

Sensor	RTTOV id	Sensor Channel #	RTTOV Channel #
HIRS	0	1 to 19	1 to 19
MSU	1	1 to 4	1 to 4
SSU	2	1 to 3	1 to 3
AMSU-A	3	1 to 15	1 to 15
AMSU-B	4	1 to 5	1 to 5
AVHRR	5	3b to 5	1 to 3
SSMI	6	1 to 7	1 to 7
VTPR1	7	1 to 8	1 to 8
VTPR2	8	1 to 8	1 to 8
TMI	9	1 to 9	1 to 9
SSMIS	10	1 to 24*	1 to 24*
AIRS	11	1 to 2378	1 to 2378
MODIS	13	1 to 17	1 to 17
ATSR	14	1 to 3	1 to 3
MVIRI	20	1 to 2	1 to 2
SEVIRI	21	4 to 11	1 to 8
GOES-Imager	22	1 to 4	1 to 4
GOES-Sounder	23	1 to 18	1 to 18
GMS imager	24	1 to 2	1 to 2
FY2-VISSR	25	1 to 2	1 to 2
FY1-MVISR	26	1 to 3	1 to 3

**channels 19-21 are not simulated accurately*

Table 3. Platforms and sensors supported by RTTOV-7 as at 1 Jan 2002. Sensors in italics are only supported by RTTOV-7.

Input ε	Forward Output ε	Tangent Linear Output ∂ε
	INFRARED CHANNELS	
0	Land=0.98/sea-ice=0.99/sea= ε_{ISEM}	∂ε about 0.98/0.99/ε_{ISEM}
Non-zero	as input	∂ε about ε input
	MICROWAVE CHANNELS	
0	Land/sea-ice computed from coefs in PSSV(2-6)/sea= $\varepsilon_{FASTEM1}$	Land/sea-ice ∂ε, about $\varepsilon_{FASTEM1}$ sea ∂ε, computed from ∂u, ∂v, ∂sst about $\varepsilon_{FASTEM1}$
-1	Land/sea-ice computed from coefs in PSSV(2-6)/sea= $\varepsilon_{FASTEM2}$	Land/sea-ice ∂ε about $\varepsilon_{FASTEM2}$ sea ∂ε, computed from ∂u, ∂v, ∂sst about $\varepsilon_{FASTEM2}$
Non-zero	as input	∂ε about ε input

Table 4. Used and output values of ε and ∂ε arrays for infrared and microwave channels for forward and gradient routines

```
<  BRUTE FORCE:      -0.2829711887E+02    0.1000000381E+01         6
<  BRUTE FORCE:      -0.2829710928E+02    0.1000000043E+01         7
<  BRUTE FORCE:      -0.2829711349E+02    0.1000000191E+01         8
<  BRUTE FORCE:      -0.2829712571E+02    0.1000000623E+01         9
<  BRUTE FORCE:      -0.2829696655E+02    0.9999949986E+00        10
<  BRUTE FORCE:      -0.2829438017E+02    0.9999035979E+00        11
<  BRUTE FORCE:      -0.2829665391E+02    0.9999839502E+00        12
<  BRUTE FORCE:      -0.2862066140E+02    0.1011434148E+01        13
<  BRUTE FORCE:      -0.3012701200E+02    0.1064667524E+01        14
<  BRUTE FORCE:      -0.2273736754E+02    0.8035226599E+00        15
---
>  BRUTE FORCE:      -0.2829711886E+02    0.1000000381E+01         6
>  BRUTE FORCE:      -0.2829710937E+02    0.1000000046E+01         7
>  BRUTE FORCE:      -0.2829711178E+02    0.1000000131E+01         8
>  BRUTE FORCE:      -0.2829712855E+02    0.1000000724E+01         9
>  BRUTE FORCE:      -0.2829702339E+02    0.9999970074E+00        10
>  BRUTE FORCE:      -0.2829381174E+02    0.9998835099E+00        11
>  BRUTE FORCE:      -0.2828812740E+02    0.9996826292E+00        12
>  BRUTE FORCE:      -0.2859223969E+02    0.1010429745E+01        13
>  BRUTE FORCE:      -0.3069544618E+02    0.1084755591E+01        14
>  BRUTE FORCE:      -0.1136868377E+02    0.4017613299E+00        15
872,873c872,873
<  PROFILE= 1 SUMRAD=   -0.7225097989E+01 SUMPROF=   -0.7225097989E+01
<  PROFILE= 2 SUMRAD=   -0.5618514327E+01 SUMPROF=   -0.5618514327E+01
---
>  PROFILE= 1 SUMRAD=   -0.7074762965E+01 SUMPROF=   -0.7074762965E+01
>  PROFILE= 2 SUMRAD=   -0.1075604858E+02 SUMPROF=   -0.1075604858E+02
```

Table 5. Example of typical differences found between NWPSAF generated output and that from the users machine. The numbers can differ from run to run.

IFAIL value	Meaning
0	Profile OK
11	Temp profile outside limits
12	Water vapour profile outside limits
13	Ozone profile outside limits
14	Surface temp outside limits
15	Surface water vapour outside limits
16	Surface wind speed outside limits
17	Zenith angle outside ISEM-6 limits
20	Input pressure levels do not match coef file
21	Temperature profile unphysical
22	Water vapour profile unphysical
23	Ozone profile unphysical
24	Surface temperature unphysical
25	Surface water vapour unphysical
26	Surface wind unphysical
27	Surface pressure unphysical

Table 6. Values for IFAIL flag from RTTOV

Annex A: RTTVI interface

CALL RTTVI (KERR, KPPF, KPNSAT, KPLEV, KPCH, KPCHUS, KPNAV, KPNSAV, KPNSSV, KPNCV, NRTTOVID, PLATFORM, SATELLITE, INSTRUMENT, NUMCHANS, PRESLEV, OTMIN, OTMAX, OQMIN, OQMAX, OOZMIN, OOZMAX, IVCH, NIU1)

RTTVI is called only once for all platforms, satellites and instruments. The table below lists the variables and gives an example of what the arrays should contain to set up RTTOV for simulating NOAA-16 AMSU-A, AMSU-B and METEOSAT-7 MVIRI radiances for up to 6 profiles in each call of RTTOV. The jpxxx array sizes are set up by the module *MOD_CPARAM.f90.* For this example setting jpnsat=3, jpch=15, jppf=6 and nlev=43 is optimum to allow all the calling options given in Annexes B-E to work.

Parameter and size if > 1	Type	IN/OUT	Description	Example of contents
KERR	INTEGER	OUT	Error if not 0	0
KPPF	INTEGER	OUT	No. of profiles	6
KPNSAT	INTEGER	OUT	No. of sensors	3
KPLEV	INTEGER	OUT	No. of levels	43
KPCH	INTEGER	OUT	No. of channels	15
KPCHUS	INTEGER	OUT	No. of channels	15
KPNAV	INTEGER	OUT	No. of profile vars	4
KPNSAV	INTEGER	OUT	No. of 2m surface vars	5
KPNSSV	INTEGER	OUT	No. of surface skin vars	6
KPNCV	INTEGER	OUT	No. of cloud variables	2
NRTTOVID	INTEGER	IN	No. of sensors	3
PLATFORM(jpnsat)	INTEGER	IN	Platform ids (Table 3)	1,1,3
SATELLITE(jpnsat)	INTEGER	IN	Satellite ids (Table 3)	16,16,7
INSTRUMENTjpnsat)	INTEGER	IN	Instrument ids (Table 3)	3,4,20
NUMCHANS(jpnsat)	INTEGER	IN/OUT	Number of channels	15,5,2
PRESLEV(nlev)	REAL	OUT	Pressure levels for coeffs	Table 2
OTMIN(nlev)	REAL	OUT	Min valid Temp	Table 2
OTMAX(nlev)	REAL	OUT	Max valid Temp	Table 2
OQMIN(nlev)	REAL	OUT	Min valid specific hum	Table 2
OQMAX(nlev)	REAL	OUT	Max valid specific hum	Table 2
OOZMIN(nlev)	REAL	OUT	Min valid ozone	Table 2
OOZMAX(nlev)	REAL	OUT	Max valid ozone	Table 2
IVCH(jpch,jpnsat)	INTEGER	IN/OUT	See note 1 below	1-15,1-5,1-2
NIU1(jpnsat)	INTEGER	IN/OUT	See note 2 below	10

Note 1. Normally IVCH on input should be initialised to zero and the output will contain all valid channel numbers for each sensor. This can be used to check RTTOV is not called with an invalid channel number. For sensors with large number of channels (e.g. AIRS) the IVCH array and NUMCHANS array can be set to non-zero values on input to allow coefficients for *only* those channels required to be read in to memory. In this case the number of channels required is in NUMCHANS and their numbers are given in the IVCH array. If IVCH is zero on input coefficients for all valid channels are read into memory.

Note 2. NIU1 is an optional parameter and if set to a non-zero value defines the fortran unit numbers through which the coefficient files are read in. This file should have already been opened.

Annex B: RTTOV interface

CALL RTTOV (KNPF, KLENPF, PPRES, PANGL, PANGS, KSURF, KSAT, KNCHPF, KCHAN, KPROF, PAV, PSAV, PSSV, PCV, PEMIS, IFAIL, PRAD, PTB, RADOV, RADO, TAU, TAUSFC, LCLOUD)

RTTOV is called for every sensor required for KPPF profiles at a time. The table below lists the variables and gives an example of what the arrays should contain for RTTOV to simulate NOAA-16 AMSU-B for 3 profiles and 4 out of the 5 channels (omitting channel 2). This assumes the calling sequence in Annex A is followed.

Parameter and size if >1	Type	IN/OUT	Description	Example of contents for AMSU-B
KNPF	INTEGER	IN	No. of profiles	3
KLENPF	INTEGER	IN	No. of levels in profiles	43
PPRES(jplev)	REAL	IN	Pressure levels (hPa)	Table 2
PANGL(jppf)	REAL	IN	Sat zenith angle (deg)	30.,32.,34.
PANGS(jppf)	REAL	Not used	Solar zenith angle (deg)	0.,0.,0.
KSURF(jppf)	INTEGER	IN	0=land, 1=sea, 2=sea-ice	1,1,0
KSAT	INTEGER	IN	Sequence number as loaded by RTTVI (see annex A)	2
KNCHPF	INTEGER	IN	No chans*No. profiles	4*3=12
KCHAN(jpchus*jppf)	INTEGER	IN	Channel numbers[+]	1,3,4,5,1,3,.
KPROF(jpchus*jppf)	INTEGER	IN	Profile numbers	1,1,1,2,2,2..
PAV(jplev,4,jppf)	REAL	IN	Profile array (Table 1)	3 profiles
PSAV(5,jppf)	REAL	IN	Surface 2m array (Table 1)	3 profiles
PSSV(6,jppf)	REAL	IN	Surface skin array (Table 1)	3 profiles
PCV(2,jppf)	REAL	IN	Cloud array (Table 1)	3 profiles
PEMIS(jpchpf)	REAL	IN/OUT	Surface emissivity (Table 4)	3 profiles
IFAIL(jppf,kpnsat)	INTEGER	OUT	See Table 6	3*3*0
PRAD(jpchpf)	REAL	OUT	Radiances in $mW/m^2/sr/cm^{-1}$	12 radiances
PTB(jpchpf)	REAL	OUT	Brightness temps in degK	12 Br. Temps
RADOV(jpchpf,2*jplev+2)	REAL	OUT	Overcast cloudy radiances[¶]	1056 rads
RADO(jpchpf)	REAL	OUT	O'cast radiance from cld top	12 radiances
TAU(jpchpf,jplev)	REAL	OUT	Layer to space transmittances	43*12 trans
TAUSFC(jpchpf)	REAL	OUT	Surface to space transmittances	12 trans
LCLOUD	LOGICAL	IN	Switch for IR cloud calcs	.false.

[+] If the array IVCH is non-zero on input to RTTVI then this channel index refers to the subset of channels requested in IVCH (normally only used for AIRS).

[¶] The RADOV array contains the following radiances for possible cloud computations outside RTTOV (e.g. used by RTTOVCLD):

RADOV (jpchus,1:njplev) : overcast radiances at given cloud top
RADOV (jpchus,njplev+1,2*njplev) : contribution to radiance of downward cloud emission at given cloud top (if LCLOUD .false. then this is zero)
RADOV (jpchus,2*njplev+1) : clear-sky radiance without reflection term
RADOV (jpchus,2*njplev+2) : reflected clear-sky downwelling radiance (if LCLOUD .false. then this is zero)

Annex C: RTTOVK interface

CALL RTTOVK(KNPF, KLENPF, PPRES, PANGL, PANGS, KSURF, KSAT, KNCHPF, KCHAN, KPROF, PAV, PSAV, PSSV, PCV, PEMIS, PAV_D, PSAV_D, PSSV_D, PCV_D, PEMIS_D, PRAD_D, PTB_D, KINRAD, LCLOUD,IFAIL,RADOV)

RTTOVK is called once for each sensor for KPPF profiles at a time. The table below lists the variables and gives an example of what the arrays should contain for RTTOVK to simulate METEOSAT MVIRI for 1 profile and both channels for a zenith angle of 30 deg. This assumes the calling sequence to RTTVI in Annex A is followed. The variables ending in _D denote direct value (same as RTTOV input/output).

Parameter and size if >1	Type	IN/OUT	Description	Example of contents for MVIRI
KNPF	INTEGER	IN	No. of profiles	1
KLENPF	INTEGER	IN	No. of levels in profiles	43
PPRES(jplev)	REAL	IN	Pressure levels (hPa)	Table 2
PANGL(jppf)	REAL	IN	Sat zenith angle (deg)	30.
PANGS(jppf)	REAL	Not used	Solar zenith angle (deg)	0.
KSURF(jppf)	INTEGER	IN	0=land, 1=sea, 2=sea-ice	1
KSAT	INTEGER	IN	Sequence number as loaded by RTTVI (see annex A)	3
KNCHPF	INTEGER	IN	No chans*No. profiles	2*1=2
KCHAN(jpchus*jppf)	INTEGER	IN	Channel numbers +	1,2
KPROF(jpchus*jppf)	INTEGER	IN	Profile numbers	1,1
PAV(jplev,4,jpchpf)	REAL	OUT	K of profile array	1 profile
PSAV(5,jpchpf)	REAL	OUT	K of surface 2m array	1 profile
PSSV(6,jpchpf)	REAL	OUT	K of Surface skin array	1 profile
PCV(2,jpchpf)	REAL	OUT	K of cloud array	1 profile
PEMIS(jpchpf)	REAL	IN/OUT	K of surface emiss (Table 4)	1 profile
PAV_D(jplev,4,jppf)	REAL	IN	Input profile array	1 profile
PSAV_D(5,jppf)	REAL	IN	Input surface 2m array	1 profile
PSSV_D(6,jppf)	REAL	IN	Input surface skin array	1 profile
PCV_D(2,jppf)	REAL	IN	In put cloud array	1 profile
PEMIS_D(jpchpf)	REAL	IN/OUT	Input surface emiss (Table 4)	1 profile
PRAD_D(jpchpf)	REAL	OUT	Radiances in $mW/m^2/sr/cm^{-1}$	2 radiances
PTB_D(jpchpf)	REAL	OUT	Brightness temps in degK	2 Br. Temps
KINRAD	INTEGER	IN	Switch (1=radiance, 2=BT)	2
LCLOUD	LOGICAL	IN	Switch for IR cloud calcs	.false.
IFAIL(jppf,kpnsat)	INTEGER	OUT	See Table 6	3*3*0
RADOV(jpchpf,2*jplev+2)	REAL	IN/OUT	K of overcast cloudy radiances¶	radiances

+ If the array IVCH is non-zero on input to RTTVI then this channel index refers to the subset of channels requested in IVCH (normally only used for AIRS).

¶ The RADOV array contains the following radiances for possible cloud computations outside RTTOV (e.g. used by RTTOVCLD):

RADOV (jpchus,1:njplev)	: overcast radiances at given cloud top
RADOV (jpchus,njplev+1,2*njplev)	: contribution to radiance of downward cloud emission at given cloud top (if LCLOUD .false. then this is zero)
RADOV (jpchus,2*njplev+1)	: clear-sky radiance without reflection term
RADOV (jpchus,2*njplev+2)	: reflected clear-sky downwelling radiance (zero if LCLOUD false)

Annex D: RTTOVTL interface

CALL RTTOVTL (KNPF, KLENPF, PPRES, PANGL, PANGS, KSURF, KSAT, KNCHPF, KCHAN, KPROF, PAV, PSAV, PSSV, PCV, PEMIS, PAV_D, PSAV_D, PSSV_D, PCV_D, PEMIS_D, RADOV_D, PRAD, PTB, RADOV, LCLOUD, IFAIL)

RTTOVTL is called once for each sensor for KPPF profiles at a time. The table below lists the variables and gives an example of what the arrays should contain for RTTOV to simulate NOAA-16 AMSU-A for 1 profile and all 15 channels for a zenith angle of 15 deg. This assumes the calling sequence to RTTVI in Annex A is followed. The variables ending in _D denote direct value (same as RTTOV input/output).

Parameter and size if >1	Type	IN/OUT	Description	Example of contents for AMSU-A
KNPF	INTEGER	IN	No. of profiles	1
KLENPF	INTEGER	IN	No. of levels in profiles	43
PPRES(jplev)	REAL	IN	Pressure levels (hPa)	Table 2
PANGL(jppf)	REAL	IN	Sat zenith angle (deg)	15.
PANGS(jppf)	REAL	Not used	Solar zenith angle (deg)	0.
KSURF(jppf)	INTEGER	IN	0=land, 1=sea, 2=sea-ice	1
KSAT	INTEGER	IN	Sequence number as loaded by RTTVI (see annex A)	1
KNCHPF	INTEGER	IN	No chans*No. profiles	15*1=15
KCHAN(jpchus*jppf)	INTEGER	IN	Channel numbers +	1,2,3,..15
KPROF(jpchus*jppf)	INTEGER	IN	Profile numbers	1,1,…1,1
PAV(jplev,4,jppf)	REAL	IN	TL of profile array	1 profile
PSAV(5,jppf)	REAL	IN	TL of surface 2m array	1 profile
PSSV(6,jppf)	REAL	IN	TL of surface skin array	1 profile
PCV(2,jppf)	REAL	IN	TL of cloud array	1 profile
PEMIS(jpchpf)	REAL	IN/OUT	TL of surface emiss (table 4)	1 profile
PAV_D(jplev,4,jppf)	REAL	IN	Input profile array	1 profile
PSAV_D(5,jppf)	REAL	IN	Input surface 2m array	1 profile
PSSV_D(6,jppf)	REAL	IN	Input surface skin array	1 profile
PCV_D(2,jppf)	REAL	IN	In put cloud array	1 profile
PEMIS_D(jpchpf)	REAL	IN/OUT	Input surface emiss (table 4)	1 profile
RADOV_D(jpchpf,2*jplev+2)	REAL	OUT	Overcast cloudy radiances¶	Radiances
PRAD(jpchpf)	REAL	OUT	TL of radiances in $mW/m^2/sr/cm^{-1}$	15 radiances
PTB(jpchpf)	REAL	OUT	TL of Brightness temps in degK	15 B. Temps
RADOV(jpchpf,2*jplev+2)	REAL	OUT	TL of overcast cloudy radiances¶	Radiances
LCLOUD	LOGICAL	IN	Switch for IR cloud calcs	.false.
IFAIL(jppf,kpnsat)	INTEGER	OUT	See Table 6	3*3*0

\+ If the array IVCH is non-zero on input to RTTVI then this channel index refers to the subset of channels requested in IVCH (normally only used for AIRS).

¶ The RADOV array contains the following TL radiances for possible cloud computations outside RTTOV (e.g. used by RTTOVCLD):

RADOV (jpchus,1:njplev)	: TL overcast radiances at given cloud top
RADOV (jpchus,njplev+1,2*njplev)	: TL contribution to radiance of downward cloud emission at given cloud top (zero if LCLOUD false)
RADOV (jpchus,2*njplev+1)	: TL clear-sky radiance without reflection term
RADOV (jpchus,2*njplev+2)	: TL reflected clear-sky downwelling radiance (zero if LCLOUD false)

Annex E: RTTOVAD interface

CALL RTTOVAD (KNPF, KLENPF, PPRES, PANGL, PANGS, KSURF, KSAT, KNCHPF, KCHAN, KPROF, PAV, PSAV, PSSV, PCV, PEMIS, PAV_D, PSAV_D, PSSV_D, PCV_D, PEMIS_D, PRAD, PTB, RADOV, KINRAD, LCLOUD, IFAIL)

RTTOVAD is called once for each sensor for KPPF profiles at a time. The table below lists the variables and gives an example of what the arrays should contain for RTTOV to simulate NOAA-16 AMSU-A for 6 profiles and 2 channels (chans 3, 8) for a zenith angle of 25 deg. This assumes the calling sequence to RTTVI in Annex A is followed. The variables ending in _D denote direct value (same as RTTOV input/output).

Parameter and size if >1	Type	IN/OUT	Description	Example of contents for AMSU-A
KNPF	INTEGER	IN	No. of profiles	6
KLENPF	INTEGER	IN	No. of levels in profiles	43
PPRES(jplev)	REAL	IN	Pressure levels (hPa)	Table 2
PANGL(jppf)	REAL	IN	Sat zenith angle (deg)	6*25.
PANGS(jppf)	REAL	Not used	Solar zenith angle (deg)	6*0.
KSURF(jppf)	INTEGER	IN	0=land, 1=sea, 2=sea-ice	6*1
KSAT	INTEGER	IN	Sequence number as loaded by RTTVI (see annex A)	1
KNCHPF	INTEGER	IN	No chans*No. profiles	2*6=12
KCHAN(jpchus*jppf)	INTEGER	IN	Channel numbers +	3,8,3,8,..
KPROF(jpchus*jppf)	INTEGER	IN	Profile numbers	1,1,2,2,3,3..
PAV(jplev,4,jppf)	REAL	OUT	AD of profile array	6 profiles
PSAV(5,jppf)	REAL	OUT	AD of surface 2m array	6 profiles
PSSV(6,jppf)	REAL	OUT	AD of surface skin array	6 profiles
PCV(2,jppf)	REAL	OUT	AD of cloud array	6 profiles
PEMIS(jpchpf)	REAL	IN/OUT	AD of surface emiss (table 4)	6 profiles
PAV_D(jplev,4,jppf)	REAL	IN	Input profile array	6 profiles
PSAV_D(5,jppf)	REAL	IN	Input surface 2m array	6 profiles
PSSV_D(6,jppf)	REAL	IN	Input surface skin array	6 profiles
PCV_D(2,jppf)	REAL	IN	In put cloud array	6 profiles
PEMIS_D(jpchpf)	REAL	IN/OUT	Input surface emiss (table 4)	6 profiles
PRAD(jpchpf)	REAL	IN	AD of radiances in $mW/m^2/sr/cm^{-1}$	Ignored for kinrad=2
PTB(jpchpf)	REAL	IN	AD of Brightness temps in degK	12 B. Temps
RADOV(jpchpf,2*jplev+2)	REAL	IN/OUT	AD of overcast cloudy radiances¶	Radiances
KINRAD	INTEGER	IN	Switch (1=radiance, 2=BT)	2
LCLOUD	LOGICAL	IN	Switch for IR cloud calcs	.false.
IFAIL(jppf,kpnsat)	INTEGER	OUT	See Table 6	3*3*0

+ If the array IVCH is non-zero on input to RTTVI then this channel index refers to the subset of channels requested in IVCH (normally only used for AIRS).

¶ The RADOV array contains the following AD radiances for possible cloud computations outside RTTOV (e.g. used by RTTOVCLD):

RADOV (jpchus,1:njplev) : AD overcast radiances at given cloud top

RADOV (jpchus,njplev+1,2*njplev) : AD contribution to radiance of downward cloud emission at given cloud top (zero if LCLOUD false)

RADOV (jpchus,2*njplev+1) : AD clear-sky radiance without reflection term

RADOV (jpchus,2*njplev+2) : AD reflected clear-sky down-welling radiance (zero if LCLOUD false)