NWP SAF

RTTOV Version 13
Release Note
(Updated for v13.2)

Version 1.2.1

23rd November 2022

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(Updated for v13.2)

This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 7 December 2016, 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, DWD and Météo France.

Change record				
Version	**Date**	**Author**	**Approved**	**Remarks**
0.1	30/03/20	JH		First draft for v13 beta
1.0	18/09/20	JH		Updates after beta testing
1.1	09/11/21	JH		Updates for v13.1
1.2	21/11/22	JH		Updates for v13.2
1.2.1	23/11/22	JH		Updates after review

Table of Contents

1. DOCUMENTATION

The following user documentation is included in the RTTOV package:

- *NWPSAF_ReleaseNote_RTTOV13.2* - this document
- *users_guide_rttov13_v1.2.pdf* - user guide giving full details of how to compile and run RTTOV and how to incorporate it into the user's application
- *rttov-quick-start.pdf* - beginner's guide to getting started with RTTOV
- *rttov_gui _v13.pdf* - user guide for RTTOV GUI
- *rttov-wrapper.pdf* - user guide for the C++/Python interface to RTTOV
- *rttov-test.pdf* - detailed description of the RTTOV test suite

2. MAIN CHANGES

Detailed lists of the changes between RTTOV v13.2, v13.1, v13.0 and v12.3 are given in section 4 of the user guide. The main changes are given below.

Changes between RTTOV v13.2 and v13.1:

VIS/IR scattering

- New MFASIS-NN (neural network) solver for visible/near-IR cloud simulations. The solver is selected by setting **opts%rt_ir%vis_scatt_model=4** and is used in conjunction with new neural network coefficient files that can be downloaded from the RTTOV coefficients web page.
- New option **opts%rt_ir%rayleigh_depol** to enable use of modified phase function accounting for molecular depolarisation in Rayleigh single and multiple scattering.
- New capability to generate aerosol optical property files based on a subset of species from the ICON-ART model (users can request files for any VIS/IR sensor via the NWP SAF helpdesk).

RTTOV-SCATT (MW scattering)

- Alternative physically-based polarisation treatment which applies to cross-track scanners as well as imagers. This is selected via the new **opts_scatt%pol_mode** option and requires an additional input file that can be downloaded from the RTTOV coefficients download page.
- Use highest temperature bin in optical property tables (previously was not used): this results in changes to outputs.
- Hydrotable generation updates:
  - Increase number of mass density points and number of temperature points in hydrotables, reduce precision to mitigate file size increase
  - New PSD options (Abel and Boutle, Illingworth and Blackman)
  - Experimental new version of Bauer (2001) melting layer over 273 - 277 K temperature bins.

General simulations

- New option **opts%rt_all%use_tskin_eff** to enable optional input of per-channel effective skin temperatures in **emissivity(:)%tskin_eff** to be used instead of single profile skin temperature.
- New option **opts%config%opdep13_gas_clip** which can be used to disable the clipping of negative individual gas optical depths resulting from the v13 predictor regression. This can mitigate convergence failures in some operational assimilation systems. Standard deviation of impact on BTs is well below 0.01 K although maximum impact is of order 0.1 K.
- Add a new **strictly_illegal** optional argument to the **rttov_user_options_checkinput** subroutine to enable checking only for strictly illegal settings and suppress errors for "dubious-but-harmless" settings.
- The **rttov_scale_ref_gas_prof** subroutine now provides the option to interpolate in log(pressure) instead of pressure.
- Add new subroutine **rttov_calc_solar_angles** to populate a profiles structure with solar zenith and azimuth angles given profile date, time, lat, lon values.
- Add new subroutine **rttov_calc_geo_sat_angles** to populate a profiles structure geostationary satellite zenith and azimuth angles given profile lat, lon values and the sub-satellite longitude.
- Not a new feature, but previously undocumented: the option **opts%dev%do_opdep_calc** can be set to false to turn off the gas optical depth calculation in RTTOV. The simulations are then run with zero gas optical depths. This may be useful for certain scattering applications. The option is available in the Python/C++ wrapper.
- Added **qmin_kgkg** and **qmax_kgkg** constants to the **rttov_const** module which give strict min/max values for input water vapour concentrations in kg/kg over moist air.

Surface emissivity/reflectance

- New SURFEM-Ocean MW sea surface emissivity model: neural network parameterisation of new PARMIO physical reference emissivity model simulating all Stokes components for channels in the range 0.5 - 700 GHz. This is specified by setting **opts%rt_mw%fastem_version=7** but this is a different model to FASTEM.
- Stokes 3/4 emissivity calculations have been implemented for FASTEM-6 based on the FASTEM-3 parameterisation. FASTEM-6 can now be used for all sensor channels below ~200GHz, including polarimetric sensors.
- FASTEM-3 relative wind direction bug fix (see FASTEM-3 bug dated 11/02/2022 in bug fix table linked below) is implemented on a switch **opts%rt_mw%fastem3_rwd_fix**, default true. Set to false to revert to previous behaviour (for users whose systems are tuned to the incorrect version and require continuity).
- Additional TL/AD/K bug fixes in FASTEM-3. These only occur for zenith angles above 60 degrees which means they are not relevant for current MW sensors.
- The BRDF atlas now extrapolates at constant value to short wavelengths which provides basic BRDFs for UV sensors (atlas to be updated with improved UV support in a future release).

GUI

- The GUI has been updated to support new features including MFASIS-NN simulations, and other new RTTOV options.
- New options are provided for installing a Python environment for the GUI including a requirements.txt file and a Dockerfile: see the GUI user guide for details.

Wrapper

- The Python/C++ wrapper has been updated to support the new features including MFASIS-NN, the new polarisation treatment in RTTOV-SCATT, the per-channel effective skin temperautre inputs, and other new RTTOV options.

Technical

- Fix AD/K issue whereby shared AD/K routines (primarily RTTOV-SCATT, but also the v13 predictor optical depth regression) can run in the wrong mode under certain conditions. There is a new optional **adk_switch** argument to **rttov_scatt_ad** and **rttov_parallel_scatt_ad** which can be used to explicitly specify an AD (0) or K (1) run. If omitted, the pre-existing behaviour pertains. For the problem to occur, it requires that some profiles passed in are not simulated for any channels which means that it should not affect most users.
- Fix issue whereby MW simulations fail if some channels are deactivated by having the channel validity flag in the *rtcoef* file set to zero. (Not issued as a bug fix as there are simple workarounds and no current or recent MW *rtcoef* files have this flag set to zero for any channels).
- Code updated for new DrHook type **jphook**.

Users should be aware that the following features are planned for removal in RTTOV v14.0:

- Flexible surface (2m p): the surface is always on the bottom profile level.
- Solar single scattering solver.
- MFASIS-LUT: this is superseded by MFASIS-NN.
- HTFRTC.
- TESSEM2 and FASTEM versions 1-5: these are superseded by SURFEM-Ocean.

Further information about RTTOV v14.0 is available here:
https://nwp-saf.eumetsat.int/site/software/rttov/future-plans/rttov-v14-plans/

Changes between RTTOV v13.1 and v13.0:

- Initial support for UV simulations: basic support for UV simulations is implemented and this will be developed further in future releases.
- MFASIS has been updated:
    - improved treatment of mixed-phase clouds. This update also changes simulated radiances with MFASIS for profiles containing *any* ice cloud (not only for profiles with mixed-phase layers).
    - capability to simulate 1.6 µm channels for supported sensors. New MFASIS LUT files are available on the coefficient download web page: these are not compatible with RTTOV v13.0 and earlier.
- The *overcast* and *radiance2* outputs are now calculated for thermal channels in aerosol simulations when the Chou-scaling solver is used. The radiances include the effect of aerosols. For solar-affected short-wave IR channels, solar radiation is not included even when the addsolar option is enabled.
- New subroutines *rttov_get_sea_emis* and *rttov_get_sea_brdf* which can be used outside of RTTOV to obtain surface emissivities and reflectances from the internal RTTOV sea surface models.

- New option *opts%rt_all%transmittances_only* to carry out transmittance calculations only (no radiances, and no surface emissivities or reflectances). This is more efficient if only transmittance outputs are required. Applies only to the direct model.
- Maximum allowed Tskin value over land increased to 1250 K to allow for lava/fires/etc.
- For SSU PMC shift simulations, the CO2 cell pressures are now initialised with the nominal values from the coefficient file. Previously they were uninitialised.
- New constants added to *rttov_const* for the indices of the RTTOV-SCATT hydrometeors in the NWP SAF hydrotables (*hydro_index_rain, hydro_index_snow,* etc): these can be used in place of hard-coded literal indices in user code for futureproofing.
- The RTTOV GUI has been updated to better support UV and VIS-only sensors.
- Minor technical updates to improve the C++ wrapper core and example code to conform to common C++ coding conventions and use recommended techniques.

Changes between RTTOV v13.0 and v12.3:

General:

- New optical depth coefficient files are available based on an updated ("v13 predictor") optical depth parameterisation and trained on LBLRTM v12.8. For visible channels this includes a new parameterisation for Rayleigh extinction which can optionally be excluded from simulations.
- The geometric altitude of each input pressure level is now available as an output in the *rttov_radiance* structure.
- Updates to allow for new polarisation in sensors like TROPICS with a fixed, but uneven mixture of H- and V-pol in each channel.

RTTOV-SCATT:

- RTTOV-SCATT allows simulations with an arbitrary number of hydrometeor types and optionally with separate cloud fraction profiles per hydrometeor.
- RTTOV-SCATT provides a new radar reflectivity simulation capability.
- New approximate treatment of polarised scattering.
- New scattering property tables.

Visible/IR scattering:

- Visible DOM simulations can optionally include full Rayleigh multiple scattering.
- Updated cloud liquid water optical properties based on updated refractive index dataset.
- A parameterisation of cloud liquid water effective diameter has been implemented for use with the CLW "Deff" visible/IR optical properties so that input Deff values are not mandatory: the parameterisation is used where the input *clwde(:)* profile values are zero.
- For visible/IR cloud simulations, the surface-space and level-to-space cloud extinction transmittances (on the surface-satellite path and excluding gas absorption) are output in the new *tau_total_cld* and *tau_levels_cld* members of the transmission structure.
- MFASIS simulations may now be run simultaneously (in the same call) as IR scattering simulations.

Surface emissivity and reflectance updates:

- The CAMEL 2007 IR atlas now provides standard deviations from the CAMEL climatology rather than the older UWIRemis standard deviations.
- For the UWIRemis and CAMEL 2007 IR emissivity atlases, the emissivity PC scores and eigenvectors are now optional outputs from the *rttov_get_emis* subroutine.

- The profile skin specularity variable introduced in RTTOV v12.3 for use with the *do_lambertian* option has been moved into the *rttov_emissivity* structure so that it can vary per-channel. This is now also an active variable in the TL/AD/K.
- The diffuse reflectances used by RTTOV for downward emitted and downward scattered radiation are available as an output in the *rttov_reflectance* structure. The value used for the diffuse reflectance can optionally be specified by the user for visible/near-IR channels.

HTFRTC:

- New coefficients are available based on LBLRTM v12.8 in ASCII format as well as netCDF.
- Emissivities are now input on centroid (predictor) wavenumbers which is consistent with the way PC-RTTOV works.
- HTFRTC now supports RTTOV's IREMIS sea surface emissivity model.
- Optimisation of the HTFRTC direct and K models.

Technical updates:

- The GUI has been updated to work with Python3, and to support new RTTOV features including all new options, input of surface specularity, and input/output of diffuse surface reflectance.
- The Python/C++ wrapper has been updated to support new features including the RTTOV-SCATT updated passive and new active simulation capabilities.
- Optimisation of the MFASIS model, which improves performance of the direct/TL/AD/K.
- Optimisation of the RTTOV-DOM AD/K models.

3. INSTALLATION

Detailed installation instructions are provided in the user guide. A brief overview is given below.

Extraction

The RTTOV v13.2 package is named *rttov132.tar.xz*. This can be downloaded from the NWP SAF website after registering with the site and agreeing to the terms of the licence. To unpack, copy the tarball to a new directory (e.g. *~/rttov132/*) which becomes your RTTOV top-level directory, and do the following:

$ tar xf rttov132.tar.xz

Compilation

It is recommended to compile RTTOV against the HDF5 library (v1.8.8 or later) as this provides the ability to read HDF5 coefficient and land surface BRDF and emissivity atlas files, and to use the GUI. In order to do this, you must first edit the file *build/Makefile.local* to point to the location of your HDF5 installation. Usually this involves:

- specifying the path to your HDF5 build in HDF5_PREFIX
- uncommenting the FFLAGS_HDF5 definition appropriate to your compiler
- uncommenting the LDFLAGS_HDF5 definition appropriate to your system

To call HTFRTC using NetCDF coefficient files through RTTOV requires that you compile against the NetCDF4 library (or you can use the ASCII coefficient files instead). To do this edit *build/Makefile.local* in a similar fashion as for HDF5 above:

- specify the path to your NetCDF build in NETCDF_PREFIX
- uncomment the FFLAGS_NETCDF definition appropriate to your compiler
- uncomment the LDFLAGS_NETCDF definition appropriate to your system

Then to compile RTTOV you can run the interactive script provided:

$ build/rttov_compile.sh

In order to use the RTTOV GUI and/or the RTTOV Python wrapper you must also have f2py installed on your system. The script detects the presence of f2py and provides the option of compiling the Python-related code.

More details including compatible compilers and information on compiling manually are given in the user guide.

Coefficient files and other ancillary data

The RTTOV package contains a commonly used subset of optical depth coefficient files. By default, coefficient files are found in the *rtcoef_rttov13/* directory. Coefficient files for all supported sensors are available from the website:
https://nwp-saf.eumetsat.int/site/software/rttov/download/coefficients/coefficient-download/

These include the optical depth coefficients for all supported sensors, the aerosol/cloud coefficient files for visible/IR scattering simulations, the hydrotable files for MW scattering simulations and the PC-RTTOV and HTFRTC coefficient files for PC simulations. The user guide provides more information about the different types of coefficient files. It is not necessary to download all coefficient files: only those relevant to the simulations you are running are required.

Similarly, the land surface BRDF and emissivity atlas files are not included in the package due to their size. These can also be downloaded from the website:
https://nwp-saf.eumetsat.int/site/software/rttov/download/#Emissivity_BRDF_atlas_data

Verifying the build

RTTOV comes with a comprehensive test suite which is described in the user guide and more fully in the *rttov-test.pdf* document. The RTTOV test scripts and data are contained in the *rttov_test/* directory. You can run a basic test to check your installation as follows.

$ cd rttov_test
$ ./test_rttov13.sh ARCH=myarch BIN=myinstalldir/bin

You must provide the name of the compiler flag file you used when compiling RTTOV (e.g. *gfortran-openmp*). If you specified an installation directory when compiling RTTOV you must provide the location of the *bin/* directory created by the build. If you did not specify an installation directory the *bin/* directory is in your top-level RTTOV folder and you do not need to pass the *BIN=* argument to the test scripts.

This script runs several simulations using coefficient files which are provided in the package and checks the direct, tangent linear, adjoint and Jacobian model output against reference data. If the tests report OK, then RTTOV has compiled correctly. (You may see some very small differences to the reference data reported, particularly for the Jacobians: these are due to compiler-dependent differences and are not cause for concern).

Several other test scripts that run different kinds of simulations are included in the package. Some of these require additional files to be downloaded from the website. The user guide provides more details.

4. LICENCE

To use this software, users need to have registered for RTTOV with the NWP SAF (https://nwp-saf.eumetsat.int), and to have agreed to the terms of the RTTOV licence agreement.

5. PACKAGE CONTENTS

The contents of the package are as follows:

```
ReleaseNote.pdf
docs/
docs/doxygen_config_dev
docs/doxygen_config_user
docs/NWPSAFLogo_gradient_S.png
docs/NWPSAF_ReleaseNote_RTTOV13.2.pdf
docs/readme_rttov_make_scaercoef.txt
docs/rttov13_svr.pdf
docs/rttov_doxygen_readme.dox
docs/rttov_gas_cloud_aerosol_units.pdf
docs/rttov_gui_v13.pdf
docs/rttov-quick-start.pdf
docs/rttov-test.pdf
docs/rttov-wrapper.pdf
docs/users_guide_rttov13_v1.2.pdf
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build/arch/nagfor-debug
build/arch/nagfor-openmp
build/arch/nec-dwd
build/arch/nec-meteofrance
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```
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gui/rcontroller/optionctrl.py
gui/rcontroller/profilectrl.py
gui/rcontroller/r1dvarController.py
gui/rcontroller/surfacectrl.py
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src/main/rttov_calcsatrefl_tl.F90
src/main/rttov_calc_solar_spec_esd.F90
src/main/rttov_calcsurfrefl_ad.F90
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src/main/rttov_convert_profile_units_tl.F90
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src/main/rttov_intavg_chan_tl.F90
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gui/test/test_clouds.py	src/main/rttov_surfem_ocean_ad_mod.F90
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gui/test/test_runpc.py	src/main/rttov_transmit_solar_tl.F90
gui/test/test_run.py	src/main/rttov_transmit_tl.F90
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rtcoef_rttov13/cldaer_ir/readme.txt	src/main/rttov_user_profile_checkinput.F90
rtcoef_rttov13/cldaer_visir/	src/main/throw.h
rtcoef_rttov13/cldaer_visir/readme.txt	src/main/yomhook.F90
rtcoef_rttov13/htfrtc/	src/Makefile
rtcoef_rttov13/htfrtc/readme.txt	src/mw_scatt/
rtcoef_rttov13/hydrotable/	src/mw_scatt_coef/
rtcoef_rttov13/hydrotable/readme.txt	src/mw_scatt_coef/artsdb/
rtcoef_rttov13/make_metopb_iasi.pl	src/mw_scatt_coef/artsdb/6-BulletRosette.rssp
rtcoef_rttov13/mfasis_lut/	src/mw_scatt_coef/artsdb/8-ColumnAggregate.rssp
rtcoef_rttov13/mfasis_lut/readme.txt	src/mw_scatt_coef/artsdb/ColumnType1.rssp
rtcoef_rttov13/mfasis_nn/	src/mw_scatt_coef/artsdb/EvansSnowAggregate.rssp
rtcoef_rttov13/mfasis_nn/readme.txt	src/mw_scatt_coef/artsdb/Flat3-BulletRosette.rssp
rtcoef_rttov13/pc/	src/mw_scatt_coef/artsdb/GemGraupel.rssp

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rtcoef_rttov13/pc/readme.txt
rtcoef_rttov13/rttov13pred101L/
rtcoef_rttov13/rttov13pred101L/readme.txt
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rtcoef_rttov13/rttov13pred54L/readme.txt
rtcoef_rttov13/rttov13pred54L/rtcoef_*.dat
rtcoef_rttov13/rttov7pred101L/
rtcoef_rttov13/rttov7pred101L/readme.txt
rtcoef_rttov13/rttov7pred54L/
rtcoef_rttov13/rttov7pred54L/readme.txt
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rtcoef_rttov13/rttov8pred101L/readme.txt
rtcoef_rttov13/rttov8pred51L/
rtcoef_rttov13/rttov8pred51L/readme.txt
rtcoef_rttov13/rttov8pred54L/
rtcoef_rttov13/rttov8pred54L/readme.txt
rtcoef_rttov13/rttov9pred101L/
rtcoef_rttov13/rttov9pred101L/readme.txt
rtcoef_rttov13/rttov9pred54L/
rtcoef_rttov13/rttov9pred54L/readme.txt
rtcoef_rttov13/rttov_coef_download.sh
rtcoef_rttov13/rttov_mviri_vis_channel_select.py
rtcoef_rttov13/vtpr.pl
rttov_test/
rttov_test/arch/
rttov_test/profile-datasets/*
rttov_test/profile-datasets-hdf/*
rttov_test/profile-datasets-py/*
rttov_test/rttov_test.pl
rttov_test/rttov_test_plot_mod.py
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rttov_test/run_example_aer_file_fwd.sh
rttov_test/run_example_aer_param_fwd.sh
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rttov_test/run_example_k.sh
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rttov_test/test_brdf_atlas.1/
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rttov_test/test_brdf_atlas.2/*
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rttov_test/test_emis_atlas.1/profiles_mw
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rttov_test/test_example.1/
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rttov_test/test_example.1/prof.dat
rttov_test/test_example.1/prof_htfrtc.dat
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rttov_test/test_rttov13_hires.sh
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rttov_test/test_rttovscatt.1/example_rttovscatt.asc
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rttov_test/test_uwiremis_atlas.sh
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src/brdf_atlas/
src/brdf_atlas/Makefile
src/brdf_atlas/mod_brdf_atlas.F90
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src/mw_scatt_coef/artsdb/IconCloudIce.rssp
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src/mw_scatt_coef/artsdb/IconSnow.rssp
src/mw_scatt_coef/artsdb/LargeBlockAggregate.rssp
src/mw_scatt_coef/artsdb/LargeColumnAggregate.rssp
src/mw_scatt_coef/artsdb/LargePlateAggregate.rssp
src/mw_scatt_coef/artsdb/LiquidSphere.rssp
src/mw_scatt_coef/artsdb/Perpendicular4-BulletRosette.rssp
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src/mw_scatt/rttov_eddington_tl.F90
src/mw_scatt/rttov_hydro_ad.F90
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