RTTOV-8 — the latest update to the RTTOV model

by
R. Saunders, Stephen English, Peter Francis, Peter Rayer, Met Office UK
Pascal Brunel, MétéoFrance,
Graeme Kelly, Peter Bauer and Deborah Salmond, ECMWF
Dave Dent, NEC

Abstract

The development of the RTTOV fast radiative transfer model — part of the EUMETSAT-sponsored NWP-SAF activities — has continued since the release of RTTOV-7 in March 2002. Over the last two years, more developments have been made, leading to the release of RTTOV-8 to users in Nov 2004. Around 70 users worldwide have already received the new code.

1. Overview of RTTOV-8

RTTOV is a radiative transfer model for very rapid calculations of top-of-atmosphere radiances for a range of space-borne infrared and microwave radiometers as listed in Table 1. The original basis for the RTTOV fast computation of transmittances is described by Eyre and Woolf (1988). This was modified for later versions of RTTOV by Eyre (1991), Rayer (1995), Saunders *et. al.* (1999) and, most recently, Matricardi (2003). Recently, the development of RTTOV (versions 6 to 8) has been carried out as part of a collaboration between the Met Office (UK), MétéoFrance and ECMWF in the framework of the EUMETSAT-funded NWP Satellite Application Facility. The latest version of RTTOV is RTTOV-8, released in November 2004. All details on the model, documentation and latest updates to the code area are available at the following website: http://www.metoffice.gov.uk/research/interproj/nwpsaf/rtm/

In summary, RTTOV-8 has the following features:

- It comprises a forward, tangent linear, adjoint and K (full Jacobian matrices) versions of the model; the latter three modules for variational assimilation or retrieval applications.
- Top-of-atmosphere radiances, brightness temperatures and layer-to-space plus surface-to-space transmittances for each channel are output for a given input atmospheric profile. There are also other layer-to-space and layer-to-surface radiances output for computing cloudy radiances.
- It takes about 170 *msec* to compute radiances for 3 profiles and 120 AIRS channels on a Sun workstation.
- The input profile must contain temperature and water vapour concentration. Optionally, ozone and carbon dioxide can also be variable gases.
- It can compute sea-surface emissivity for each channel internally or use a value provided by the user. The ISEM-6 model is used for the infrared. The FASTEM-3 model is used for the microwave.
- Cloud-top pressure and effective cloud amount can be specified for simple, single-layer cloudy radiance calculations.
- A 'wrapper code' allows RTTOV to be used to compute more complicated, multi-layer, cloudy radiances (RTTOV_CLD) with various overlap assumptions.
- A new wrapper code allows RTTOV to be used to compute rain-affected microwave radiances (RTTOV_SCATT).
- It can reproduce the results for RTTOV-71 (except for RTTOV_CLD).
- It supports all the sensors given in the Table 1.
- It is written in Fortran-90, and runs under unix or linux.
- It has been tested on a range of platforms including linux PCs.

It should be noted that, for those RTTOV-7 users who want to use the new RTTOV-8 code but do not want to change their code, an interface routine is provided to allow RTTOV-8 to be called from an 'RTTOV-7 like' interface in the users code. However this is only for a limited set of options for the forward model only.

Platforms	Sensor	Channels simulated
TIROS-N NOAA-6-18 NOAA-2-5	HIRS, MSU, SSU, AMSU-A AMSU-B, MHS, AVHRR, VTPR	1-19, 1-4 1-3, 1-15 1-5, 1-5, 1-3,1-8
DMSP F-8-15	SSM/I	1-7
DMSP F-16	SSMI(S)	1-24
Meteosat-2-8	MVIRI SEVIRI	2 4-11
GOES-8-12	Imager Sounder	1-4 1-18
ERS-1/2 ENVISAT	ATSR AATSR	1-3 1-3
GMS-5, MTSAT	Imager	1-3,1-4
Terra Aqua	MODIS,AIRS AMSU-A, HSB, AMSR	1-17, 1-2378 1-15, 1-4,1-14
TRMM	TMI	1-9
Coriolis	WindSat	1-10
FY-1, FY-2	MVISR, VISSR	1-3, 1-2

Table 1. Sensors currently simulated by RTTOV-7 and 8.
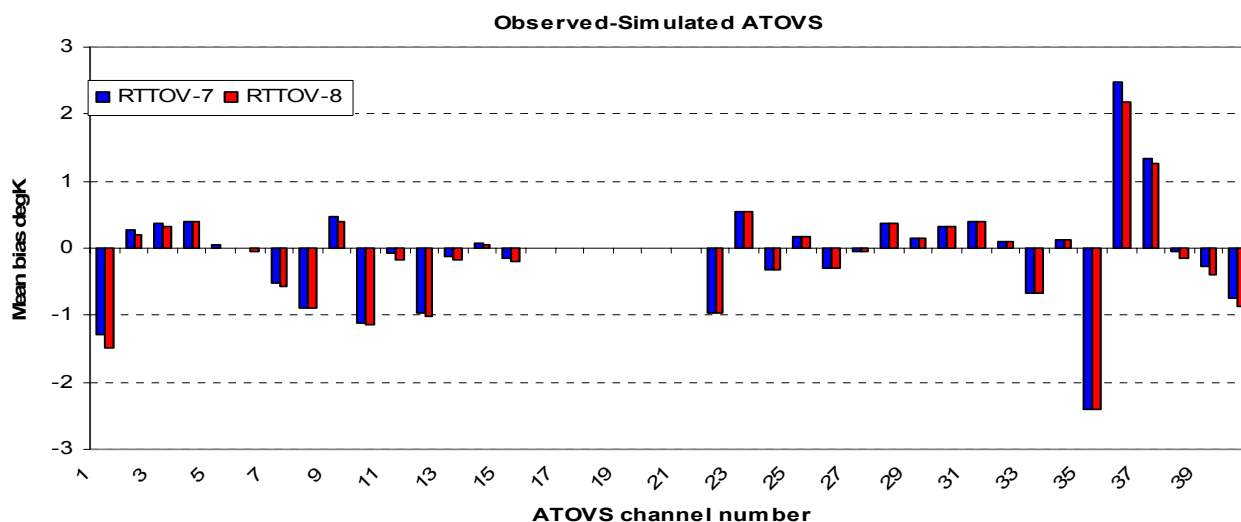

Figure 1. Comparisons between RTTOV-7 and RTTOV-8 in the ECMWF model (same predictors).

2. Validation of RTTOV-8 model

There has been an extensive series of tests run to ensure the performance of RTTOV-8 matches or exceeds that of RTTOV-7 in terms of accuracy of simulations and run time. The results are described in detail in the RTTOV-8 science and validation report (hereafter referred to as the SVR) which is available at:
http://www.metoffice.gov.uk/research/interproj/nwpsaf/rtm/rtm_rttov8.html
A few examples are given here.

To ensure the new RTTOV-8 code can provide the same results as RTTOV-7 using the same predictors it was run in the ECMWF Integrated Forecasting System for 21 days in March 2004. The mean biases between the Observed ATOVS radiances (HIRS 1-20 and AMSU 21-40) are shown in Figure 1. The biases are all very similar as expected, the small differences being due to slightly different samples being used due to differences in the quality control checks. The differences between the standard deviation of the differences are negligible.

For the new set of predictors (see Tables 2 and 3 of the SVR) a new set of GENLN2 and kCarta line-by-line transmittances for the 52 diverse ECMWF model profiles at 43 levels and 101 levels were computed as new dependent sets. In this case water vapour transmittances are separated out into line absorption and continuum absorption in contrast to the earlier GENLN2 transmittances. Coefficients were derived for both 43 levels (to match the old datasets) and on a new set of 101 AIRS pressure levels defined on the RTTOV web page at:
http://www.metoffice.com/research/interproj/nwpsaf/rtm/diverse_52profiles_101L.dat.

In addition CO_2 was optionally made a variable gas with its own set of optical depth predictors. The RTTOV-8 simulations are compared with kCarta line by line simulations which are the dependent dataset from which the coefficients were derived. Figure 2 compares the RTTOV and kCarta differences for the RTTOV-7 optical depth predictors and RTTOV-8 optical depth predictors for the 52 profile dependent set for HIRS radiances.

In terms of bias the RTTOV-8 predictors generally have the same or lower bias but differences are all at the 0.01K level. The move to 101 levels has little effect on the biases. When variable CO_2 is included on 101 levels the biases are unchanged for some channels except HIRS channels 1-7, 15-16 where there is an increase in the bias. In terms of standard deviation of the differences the change of predictors has only a small effect but increasing the number of levels from 43L to 101L does reduce the standard deviation by up to 50% for some of the HIRS water vapour channels. The standard deviation increases for variable CO_2 for the same HIRS channels as listed above.

Finally to compare use of computer resources Table 2 shows a comparison run on a SunOS 5.9 workstation for RTTOV-71 and RTTOV_8_5 versions.

3. RTTOV latest developments

Since the release of RTTOV-8_5 in November 2004 upgrades to the code have been made which have improved various aspects of the code and performance.

- The performance on vector machines has been improved and the code updates are now available from the RTTOV-8 web page.
- A new RTTOV-7-like interface for the RTTOV K-code will be available shortly.

Resource	RTTOV-7	RTTOV_8_5 ASCII	RTTOV_8_5 BINARY
Disk space required (excl. AIRS coeffs) *Mbytes*	86	66	66
Memory for AIRS (3 profiles 120 chans) *Mbytes*	87	17	11
CPU for direct code (3 profs 120 chans) *msecs*	169	170	141
CPU for K code (3 profs 120 chans) *msecs* (preprocessing is ignored for this time)	441	378	378

Table 2. Comparisons of computer resources for RTTOV-71 and RTTOV8_5 for an AIRS simulation of 120 channels. The times for a binary coefficient file read and an ascii coefficient file read are included.
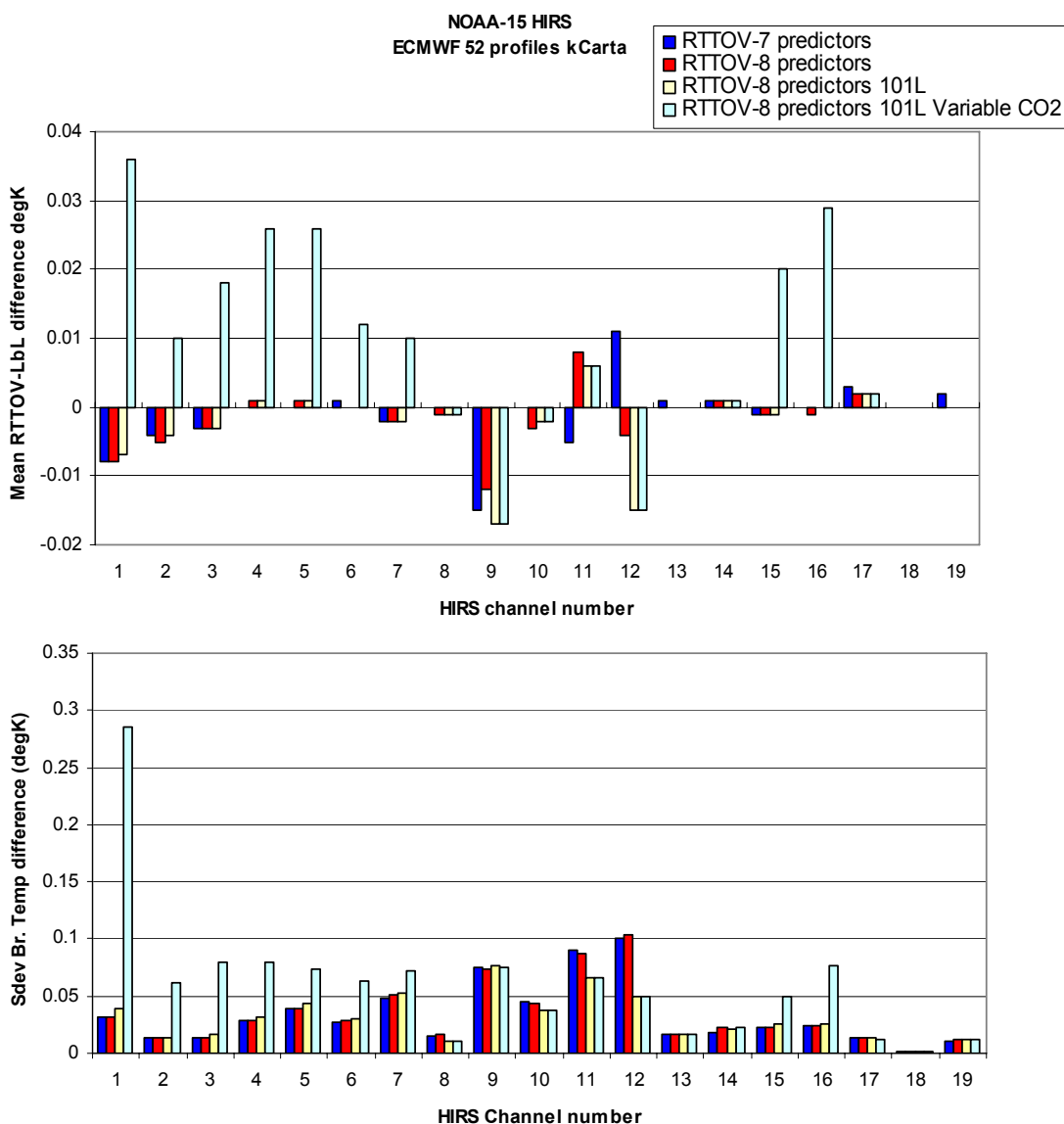

Figure 2. Comparison of RTTOV-7 on 43 levels and RTTOV-8 optical depth predictors on 43 levels and 101 levels with and without variable CO$_2$. The differences are computed for 52 diverse profiles, 6 viewing angles with kCarta as the LbL model for all coefficients.

- RTTOV_SCATT is being rewritten to be better optimised and work for all microwave sensors. New code will be available at the end of 2005.
- A bug in the new RTTOV-8 predictors has been corrected and an update is available from the web site.
- Various bugs in the microwave sea-surface emissivity code have been corrected and updates are available from the web site.
- More coefficient files for the RTTOV-8 predictors will be available later this year when tests are completed.
- A IASI coefficient file is being prepared.

An updated version of the RTTOV-8 code will be available for distribution by the end of 2005 which will include the new RTTOVSCATT code.

4. How to obtain the code

For your free copy, visit the URL below and click on 'software requests' in the right panel. A poster on the current status of the fast radiative transfer model, RTTOV, was given during ITSC-14 and can be viewed from the ITSC-14 agenda.
For full details all the RTTOV documentation it can be viewed at:
http://www.metoffice.gov.uk/research/interproj/nwpsaf/rtm/

5. References

Eyre J.R. and H.M. Woolf 1988. Transmittance of atmospheric gases in the microwave region: a fast model. *Applied Optics* **27** *3244–3249*

Eyre J.R. 1991. A fast radiative transfer model for satellite sounding systems. *ECMWF Research Dept. Tech. Memo. 176 (available from the librarian at ECMWF).*

Matricardi, M. 2003. RTIASI-4, a new version of the ECMWF fast radiative transfer model for the infrared atmospheric sounding interferometer. *ECMWF Research Dept. Tech. Memo.* **425**. http://www.ecmwf.int/publications

Rayer P.J. 1995. Fast transmittance model for satellite sounding. *Applied Optics, 34 7387– 7394.*

RTTOV-8 Science and Validation Report. Available from RTTOV-8 web page: http://www.metoffice.gov.uk/research/interproj/nwpsaf/rtm/rtm_rttov8.html

Saunders R.W., M. Matricardi and P. Brunel 1999. An Improved Fast Radiative Transfer Model for Assimilation of Satellite Radiance Observations. *QJRMS, 125, 1407–1425.*

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