A new fast radiative transfer model - RTTOV-9

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1. Introduction

The development of the fast Radiative Transfer for (A)TOVS (RTTOV) model has continued since the release of RTTOV-8 in Nov 2004. Over the last two years, more developments have been made, leading to the imminent release of RTTOV-9 to users in late 2007. Around 260 users worldwide have received the RTTOV-8 code from the NWP-SAF to date. RTTOV is used for radiance assimilation in NWP models, simulating current and future satellite observations and as part of physical retrieval schemes. More details on the RTTOV model can be found on the web site: http://www.metoffice.gov.uk/research/interproj/nwpsaf/rtm

2. What is RTTOV-9?

RTTOV is a radiative transfer model to compute very rapid calculations of top of atmosphere radiances for a range of space-borne infrared and microwave radiometers viewing the Earth's atmosphere and surface. 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), Matricardi (2003) and Matricardi (2005). The development of RTTOV (versions 6–9) has been carried out as part of collaboration between the Met Office (UK), MétéoFrance and ECMWF in the framework of the EUMETSAT-funded NWP Satellite Application Facility and also other EUMETSAT sponsored activities. All documentation and latest updates to the code are available at the website above. In summary, RTTOV-9 has the following attributes:

- 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 transmittance 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 0.5 *msec* to compute radiances for 20 HIRS channels for one profile on a Linux PC
- The input profile must have temperature and water vapour concentration. Optionally, ozone, methane, nitrous oxide, carbon monoxide 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 (Sherlock, 1999) is used for the infrared. The FASTEM model (DeBlonde and English, 2001) is used for the microwave
- The reflected solar radiation in the shortwave IR can optionally be included
- Correction of path lengths due to refraction can optionally be included
- Cloud-top pressure and effective cloud amount can be specified for simple, single-layer cloudy radiance calculations
- A full cloud water/ice profile can be supplied for cloudy radiance simulation with various overlap assumptions
- A wrapper code allows RTTOV to be used to compute rain-affected microwave radiances (RTTOV_SCATT) Bauer et. al. (2006)
- It supports all the sensors given in the Table 1 for all the platforms the sensor has flown on
- It is written in Fortran-90, and run under unix or linux

- It has been tested on a range of platforms including vector and scalar supercomputers and linux PCs

3. The differences between RTTOV-8 and RTTOV-9

This section itemises the main differences between the current RTTOV-8 model version 87and the new RTTOV-9 model version 91:

- Transmittances for the high resolution infrared sensors have been recomputed to include more up to date spectroscopy
- Optional addition of parameterised aerosol scattering for a range of different user chosen aerosol components mixed to form a type or selection of an aerosol climatological regime
- Optional addition of cloud (water or ice) parameterised scattering for infrared
- Linear in transmittance approximation for the Planck function to improve the accuracy of the layer radiance computation
- Optionally include reflected solar radiation for wavelengths below 5 microns.
- More active trace gases (i.e. CO, CH_4, N_2O)
- Further optimisation of optical depth computations for all gases for high resolution IR sensors
- Inclusion of an altitude dependent value of the local zenith angle (previous models assumed plane parallel) and optionally allowing for atmospheric refraction
- The Mie scattering tables used by RTTOV_SCATT have been updated to increase their dynamic range
- Change of user interface to optionally allow profiles on user defined levels and better mapping of computed Jacobians on to user levels
- Simplified user interface to avoid the need to specify polarisation
- Improved performance over RTTOV-8 on vector and scalar machines for the same calculations

4. Sensors simulated by RTTOV-9

All supported versions of RTTOV (i.e. versions 7, 8 and 9) can simulate a range of different infrared and microwave sensors as listed in Table 1. This list is added to as required and plans are underway to include the NPOESS and Chinese FY-3 sensors during the next year. Note that only the infrared and microwave channels can be simulated at present. There is also a need to consider adding historical satellite sensors to the list for reanalyses and climate data record applications. Users can request new sensors to be added to the list supported by RTTOV. There have also been a number of studies where RTTOV has been used to simulate radiances from hypothetical sensors in order to evaluate their utility for atmospheric sounding.

Platforms	Sensor	Channels
TIROS-N NOAA-6-18 NOAA-2-5 METOP-2(A)	HIRS, MSU, SSU, AMSU-A AMSU-B, MHS, AVHRR, VTPR IASI	1-19, 1-4 1-3, 1-15 1-5, 1-5, 1-3,1-8 1-8461
DMSP F-8-15	SSM/I	1-7
DMSP F-16	SSMI(S)	1-24
Meteosat-2-9	MVIRI SEVIRI	2 4-11
GOES-8-13	Imager Sounder	1-4 1-18
ERS-1/2 ENVISAT	ATSR AATSR	1-3 1-3
GMS-5, MTSAT-1,2	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*. List of sensors and platforms supported by RTTOV as of September 2007.**

5. Comparisons between RTTOV-7, RTTOV-8 and RTTOV-9 for ATOVS

The plot below shows the standard deviation of the differences between line-by-line computed brightness temperatures and those computed by various versions of the RTTOV code using the same predictors. This verifies the correct implementation of the code and the performance for the original RTTOV-7 predictors which are still available in RTTOV-9. The computations were done for 117 diverse profiles and 5 different viewing angles. A fixed surface emissivity of 1 was assumed for all HIRS (1-20) and 0.65 for AMSU (21-40).

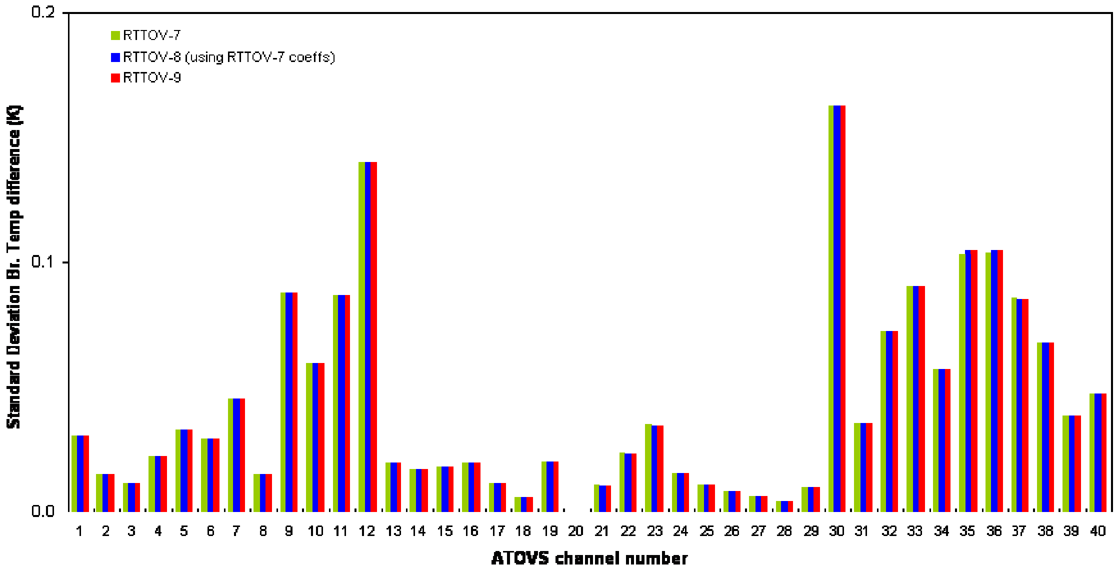

***Figure 1.* Comparison of the performance of RTTOV-7, 8 and 9 for 117 diverse profiles assessed by the standard deviation of the difference between RTTOV and line-by-line computed radiances.**

6. Comparison with other models

It is important to not only validate the absolute performance of RTTOV-9 but also compare it with other equivalent RT models. A recent model intercomparison of simulations for the AIRS spectrometer has been carried out by Saunders *et. al.* (2007). The plot below shows a histogram of RT model differences for a variety of different RT models, for nadir view simulations of the AIRS radiances for different spectral regions. The RFM line-by-line model is used as the reference model against which all the other RT models are compared. The columns on the far right give the AIRS instrument noise for a 250K brightness temperature scene. The RTTOV-9 results are the same as the RTTOV-7 or RTTOV-8 differences plotted depending which predictor set is chosen. This demonstrates RTTOV has a similar performance to other RT models in all spectral regions. There are also other aspects of the RT models compared in Saunders et. al. (2007) for example the temperature, water vapour and ozone Jacobians and a comparison with measured AIRS radiances over the western tropical Pacific ARM site.

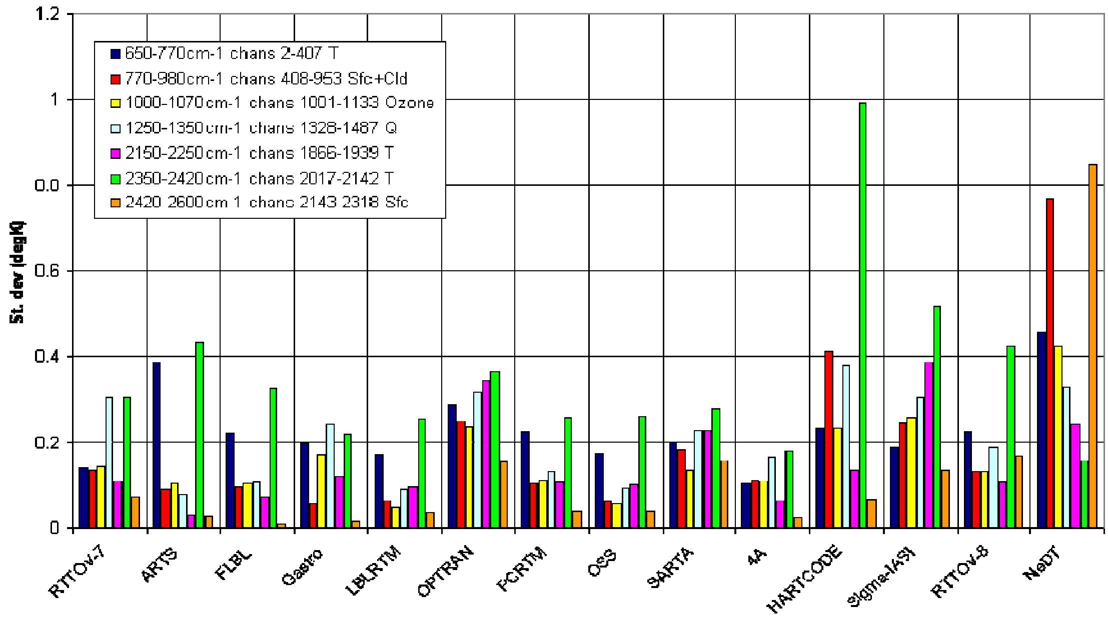

***Figure 2*. Comparison of RT models for AIRS averaged over different spectral regions together with the AIRS instrument noise on the far right.**

7. References

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