Status of RTTOV-7 and plans for RTTOV-8

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Introduction

Fast radiative transfer (RT) models are an important tool both for assimilation of satellite radiances in numerical weather prediction (NWP) models and performing physical retrievals. Fast RT models should include both the forward model, which computes satellite radiances for a given profile vector, and its jacobian which, for a given profile, computes the partial derivative of the change in radiance with respect to each of the input profile variables. The latest version of RTTOV, RTTOV-7, was released in March 2002 by the NWP Satellite Application Facility (SAF) and has been distributed to over 54 users worldwide. RTTOV-7 has several improvements over the previous version, RTTOV-6, that are described in the paper by Saunders *et. al.* (2002) and presented at ITSC-12. The main upgrades were: improved water vapour and ozone channel simulation, improved microwave surface emissivity model, support for AIRS, MODIS and SSM/I(S), additional routines for simulating multi-layer cloudy radiances and a new more flexible organisation of the coefficient ingest code. In January 2003 a slightly modified version of RTTOV-7, referred to as RTTOV-71, replaced the March 2002 version which took care of some minor bugs in the original code.

This paper updates the status of RTTOV-7, since ITSC-12, and outlines the scientific and technical upgrades being made for the next version of RTTOV due to be released in Feb 2004. The RTTOV-7 software is available to users on request from the NWP SAF (mailto:rttov.nwpsaf@metoffice.com) on a CDROM or via FTP. The RTTOV-7 documentation can be viewed on the NWP SAF RTTOV web site at http://www.metoffice.com/research/interproj/nwpsaf/rtm/ and will be updated from time to time. Technical documentation about the software can be found in the RTTOV-7 installation and users guide and, at a more detailed level, in the RTTOV-7 technical report. Details of the scientific changes and validation tests are in the RTTOV-7 science and validation report (2002) also available from the web site. Users of the code are invited to submit comments for improvements or report bugs to mailto:rttov.nwpsaf@metoffice.com. An RTTOV email newsgroup exists to share experiences, report bugs and broadcast information on updates to the coefficient files or code. Just send a request to this email to be included on the newsgroup.

Current status of RTTOV-7

The current version of RTTOV-7 is RTTOV-71 released by the NWP-SAF in January 2003. This version corrected all the known bugs in the code updated at:
http://www.metoffice.com/research/interproj/nwpsaf/rtm/rttov7_bugs.html
In addition new coefficient files have been released that were not part of the RTTOV-7 export package. They are:

- NOAA-17 ATOVS & AVHRR
- AQUA MODIS, AMSU-A, HSB, AIRS & AMSR-E
- ADEOS-2 AMSR

These files can be downloaded from the RTTOV-7 web page. A complete list of sensors now supported by RTTOV-7 is given at Table 1. There are plans to include coefficients to simulate

NOAA-18 ATOVS (including MHS), MTSAT imager, METOP-1 ATOVS and IASI, and Windsat. The latter two sensors will be for RTTOV-8 only.

The RTTOV-7 code (or earlier versions) is being used in many NWP centres for radiance assimilation. A survey was made in 2003 to assess, which sensors the users were simulating with the code and the results are presented in Figure 1. Currently ATOVS, SSM/I and SEVIRI are the main sensors being simulated.
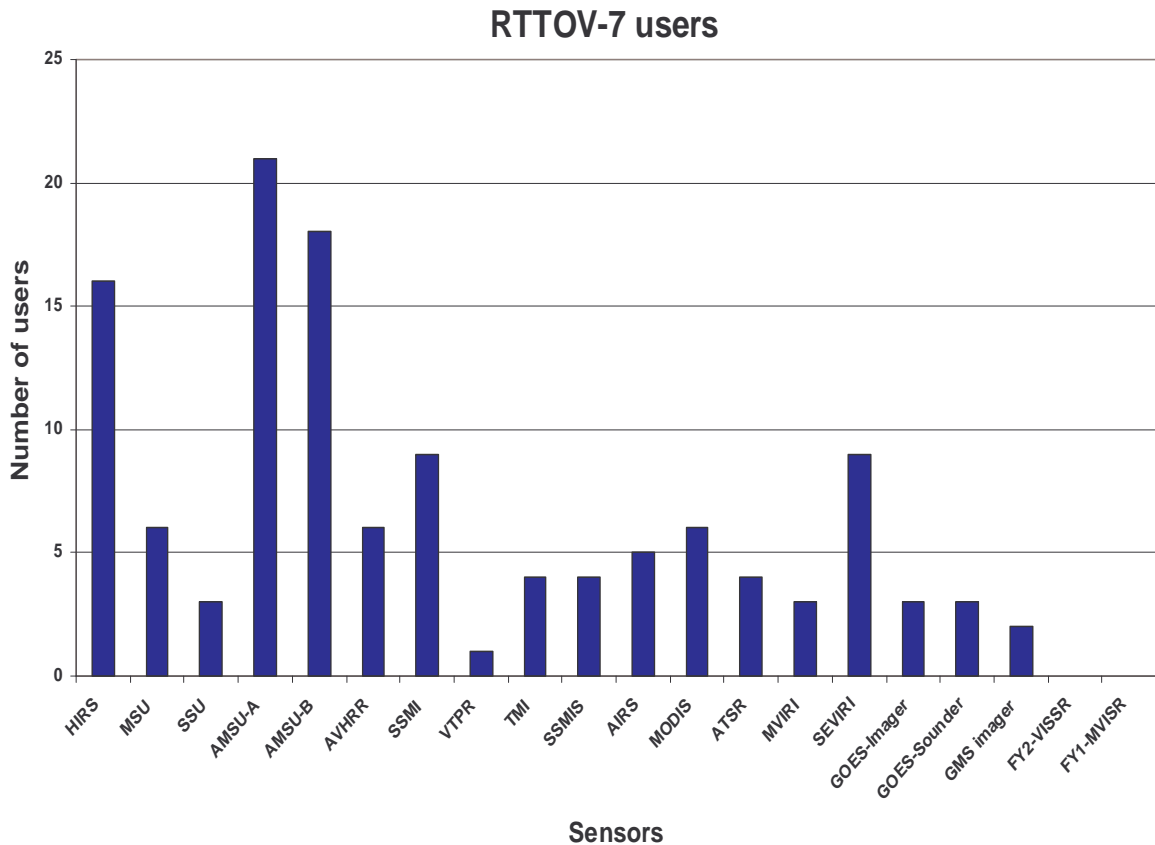

Figure 1 Results of user survey on which sensors are being simulated

One problem has been reported related to the water vapour jacobians in the stratosphere. Unrealistic spikes have been noted for some water vapour profiles in the 5-100hPa level for the AMSU-A channels 5-11. Some examples are shown in Figure 2. This is believed to be due to the low variability in the water vapour transmittances used in the training set causing spurious features in the water vapour transmittances computed from some profiles. As these levels are well above most of the water vapour in the atmosphere the simplest solution is not to allow levels above 115hPa to affect the water vapour profiles in the assimilation/retrieval. Failure to do so can cause problems in the minimisation process.

A significant limitation of the RTTOV model is that the transmittances are only computed on 43 atmospheric levels. This is sufficient for most filter radiometers but for the new advanced sounders it has been shown (Sherlock, 2001) that about 60 levels are required for accurate simulations.

Significant biases exist for very broad spectral channels (e.g. MVIRI 6.7µm, AVHRR 3.7µm) as the Planck function varies significantly across the band. To reduce the mean biases Planck weighted

transmittances have been shown to be an effective way to compute the coefficients from and the results are presented in the poster presented at ITSC-13 by Brunel and Turner (2003).

Platform/Sensor	Sat ids	Channels
NOAA HIRS	6-17	1 to 19
NOAA MSU	6-14	1 to 4
NOAA SSU	6-14	1 to 3
NOAA AMSU-A	15-17	1 to 15
NOAA AMSU-B	15-17	1 to 5
NOAA AVHRR	6-17	3b to 5
DMSP SSMI	8-15	1 to 7
NOAA VTPR	2-5	1 to 8
TRMM TMI	1	1 to 9
DMSP-SSMIS	16	1 to 24[*]
EOS-AIRS	2	1 to 2378
EOS-MODIS	1-2	1 to 17
EOS-AMSU-A	2	1 to 15
EOS-HSB	2	1 to 4
EOS/ADEOS AMSR	2/2	1 to 14
ESA-(A)ATSR	1-3	1 to 3
METEOSAT	2-7	1 to 2
MSG SEVIRI	1	4 to 11
GOES-Imager	8-12	1 to 4
GOES-Sounder	8,10,11	1 to 18
GMS imager	5	1 to 2
FY2-VISSR	2	1 to 2
FY1-MVISR	3-4	1 to 3

mesospheric channels 19-21 are not simulated accurately

Table 1. Platforms and sensors supported by RTTOV-7 as at 1 Nov 2003.

Developments in line-by-line model database

Infrared model
The RTTOV-7 model is based on the same line-by-line (LbL) model transmittances as used for RTTOV-5/6 that were computed using GENLN2 (Edwards, 1992) on 43 pressure levels from 0.1 to 1013hPa with a diverse radiosonde profile set selected from the TIGR v2 dataset. The computations were performed 7 years ago based on HITRAN-96 spectroscopy and the CKD2.1 water vapour continuum. There are now more recent versions of the spectroscopic datasets available and so it was decided to update the dependent set of transmittances this time using HITRAN-2000 and CKD2.4. In addition a new set of 51 diverse profiles has been generated from ECMWF reanalysis fields that allow dynamically consistent profiles of temperature, water vapour and ozone to be generated from the surface to 0.1hPa. These profiles are described in more detail in Chevallier *et. al*. (2000). For the line-by-line model transmittance calculations they were re-interpolated on to the AIRS 101 pressure levels, which were felt to be sufficient for any advanced sounder simulations. For this set of calculations the water vapour continuum absorption was computed separately in preparation for RTTOV-8 that will have the option of separate predictors for the water vapour line and continuum absorption. Also a separate set of CO_2 transmittance profiles were computed to allow the option of retrieving CO_2 using RTTOV-8. The current status (Nov 2003) is that all of the GENLN2 line-by-line model computations have been completed and the convolutions with the instrument filter responses are now underway after the transmittances have been interpolated to the required number of levels. In addition it is also planned to use transmittance calculations from the latest version of

kCARTA (Strow *et. al,.* 1998) as the treatment of CO_2 line mixing has been improved for this model and been validated by comparison with AIRS measurements.
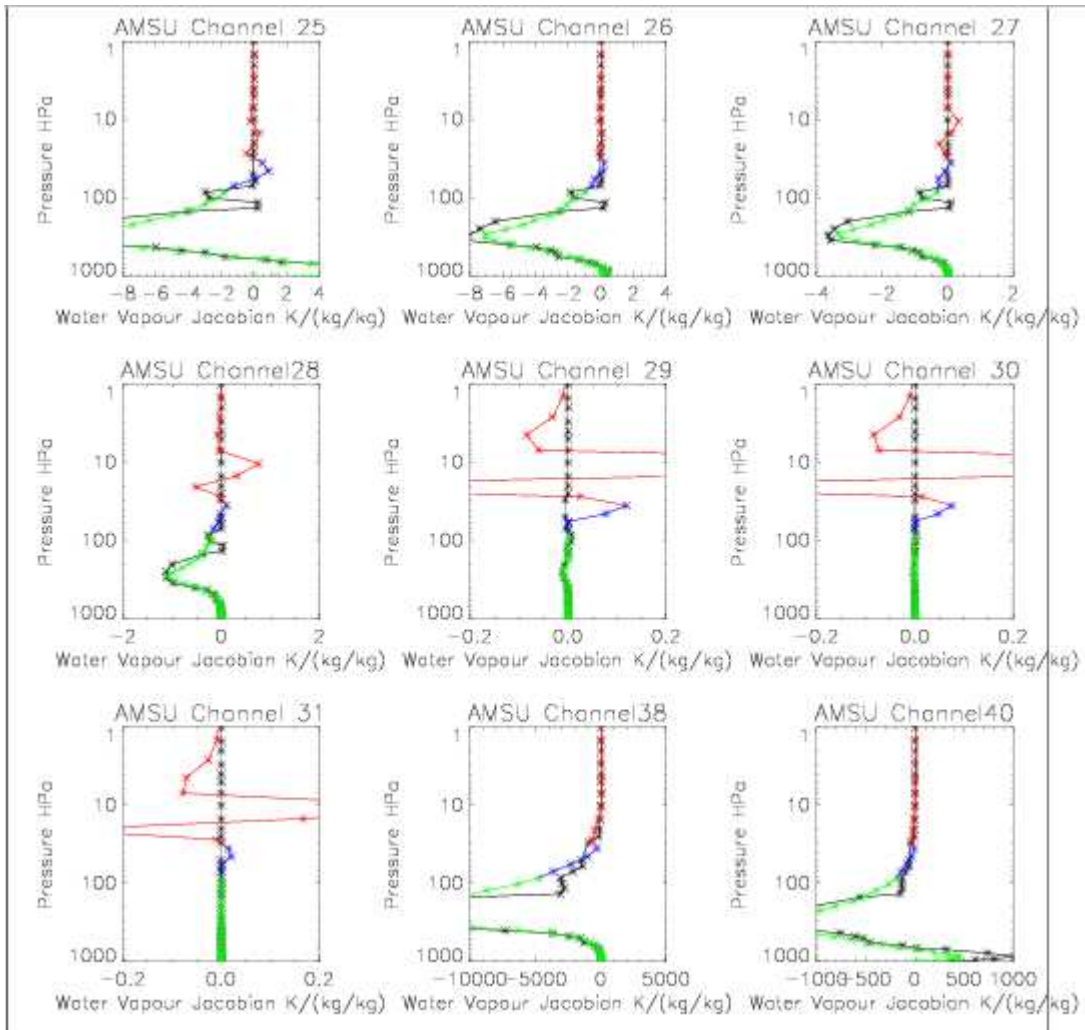

Figure 2. Spikes observed in RTTOV-7 water vapour jacobian. Black denotes RTTOV-5 values and the red, blue and green line denotes the RTTOV-7values.

Microwave model
The Liebe MPM89 model (Liebe *et. al.,* 1989) is still the model used for the microwave water vapour transmittance and MPM92 for the oxygen transmittance calculations. Comparisons have been made with other microwave models (e.g. Garand *et. al.,*2001) but only small differences are seen and so there are no plans to update the microwave transmittances in the short term.

Plans for RTTOV-8

Preparations are now well underway within the NWP-SAF for the next version of RTTOV. The main developments are:
- The code has been completely rewritten using all features of Fortran-90.
- Allow easier use of different number of levels (e.g. ~45 for ATOVS, ~60 for AIRS).
- Revise predictors (number, robustness) and separate water vapour continuum.
- Include CO_2 as an optional variable gas.
- Include scattering code around RTTOV-8 to allow simulation of rain affected microwave radiances.
- Allow simulation of fully polarimetric microwave simulations.
- Improve infrared cloudy radiance simulations.

- Add capability for IASI/CrIS simulations.
- Provide a RTTOV-7 like interface so that if users don't want to change their interface they can recompile the code using the new RTTOV-8 library.

The plan is to release RTTOV-8 to users in early 2004. It will be announced on the web page and on the email group. It will be free of charge for all non-commercial users who sign the licence agreement. For the longer term the NWP SAF is being extended into an initial operational phase and as part of this will be the further development of RTTOV-8 to RTTOV-9 due to be released in early 2007.

Acknowledgements

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