Results of a comparison of radiative transfer models for simulating AIRS radiances

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At the workshop for Soundings from High Spectral Resolution Observations in May 2003, an AIRS radiative transfer model comparison was proposed under the auspices of the ITWG. Results from 14 models have been submitted. The aim of the intercomparison is (i) to compare the forward model calculations for all AIRS channels from all models for 52 diverse profiles and one tropical Pacific profile coincident with AIRS data; (ii) to estimate forward model error covariances; (iii) to assess the jacobians from each model using a measure of fit for a limited selection of channels; and (iv) to document the time taken to run each model. Some results of this intercomparison are given below.

1. Comparisons undertaken and results submitted

The 14 radiative transfer models listed below computed brightness temperatures for all 2378 AIRS channels using 52 diverse atmospheres sampled from ECMWF model analyses. In addition, one profile from the Western Tropical Pacific ARM site coincident with AIRS observations was also modelled (see Section 3). Results were submitted for three zenith angles — nadir, 45 deg and 60 deg — but only the nadir results are presented here. A subset of the models also computed temperature, water vapour and ozone jacobians for 20 of the AIRS channels listed in **Table 1**. In addition, model run times were also documented. RFM, a line-by-line model, was used as a reference for the results presented below. The aim of this study is to allow the error characteristics of AIRS fast RT models to be better estimated for retrieval and data assimilation applications.

Model	Participant	Direct?	Jacobian?
RTTOV-7	R. Saunders, METO	Yes	Yes
RTTOV-8	R. Saunders, METO	Yes	Yes
Optran	Y. Han, NESDIS	Yes	Yes
OSS	J-L. Moncet, AER	Yes	Yes
LBLRTM	J-L. Moncet, AER	Yes	Yes
RFM	N. Bormann, ECMWF	Yes	Yes
Gastropod	V. Sherlock, NIWA	Yes	Yes
ARTS	A. Von Engeln, Bremen	Yes	No
SARTA	S. Hannon, UMBC	Yes	No
PCRTM	Xu Liu, NASA, LRC	Yes	Yes
4A	S. Heilliette, LMD	Yes	Yes
FLBL	D.S. Turner, MSC	Yes	Yes
σ-IASI	C. Serio, Uni Basilicata	Yes	Yes
Hartcode	F. Miskolczi, NASA, LRC	Yes	No

2. Comparison of forward model calculations

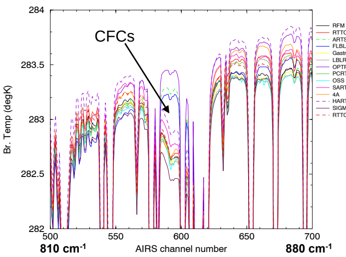

Figure 1: *Comparison of AIRS RT models for the mean profile of the 52 set. The differences around channel 590 are due to the different treatment of CFCs in the models*

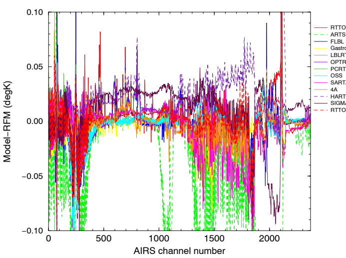

Figure 2: *Mean brightness temperature difference for each AIRS channel of the 14 model simulations differenced with the RFM model for 52 diverse profiles and nadir view simulations*

For the forward model comparisons, **Figure 1** shows a portion of the spectrum from 810 to 880 cm^{-1} for the mean profile (number 52). Some differences between the different RT models are clear in this part of the spectrum. The obvious differences at channel 590 (845 cm^{-1}) are due to the different way each model treats the absorption due to CFCs. There are also significant differences in the 'window' regions between the lines due to differences in the water vapour continuum formulation. Those fast models which are based on a line-by-line model included in the study generally follow the model on which they were trained on. For example, OSS follows LBLRTM closely. RTTOV-7, based on GENLN-2, which is similar to RFM, does follow RFM below 850 cm^{-1} but there are significant differences in the window regions at higher frequencies due to continuum differences. **Figure 2** shows the mean channel differences for all the models. Significant differences are seen for the ARTS model, which predicts lower radiances than the others in the higher absorption bands. Sigma-IASI is slightly warmer than the other models in the atmospheric window and cooler at shorter wavelengths. Hartcode has a warm bias from 1350 to 2300 cm^{-1}. The differences for each model are summarised in **Figures 3** and **4** where the values are binned as histograms and integrated over all the channels. *It is important to bear in mind that these differences are with respect to RFM and this may not be the best reference, so the biases are only relative.* With a few exceptions, the differences of the models from RFM are similar.

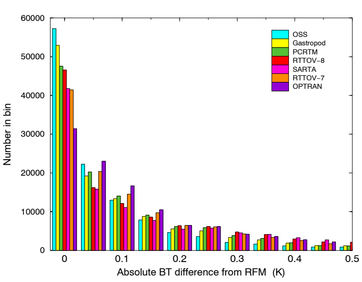

Figure 3: *Brightness temperature difference histogram for all AIRS channels for the fast RT model simulations differenced with the RFM model for 52 diverse profiles and nadir view simulations*

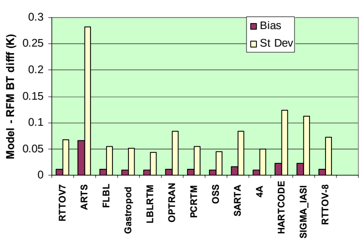

Figure 4: *Channel averaged brightness temperature mean difference and standard deviation of the difference for the RT model simulations differenced with the RFM model for 52 diverse profiles and nadir view simulations*

3. Comparisons with AIRS measurements

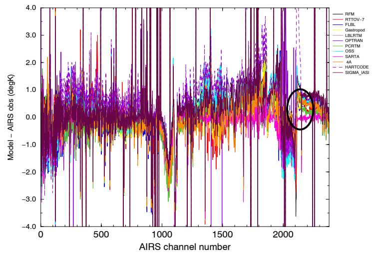

Figure 5: *Modelled – observed differences for AIRS channels over W. Pacific ARM site for nadir angle of 11.55 deg*

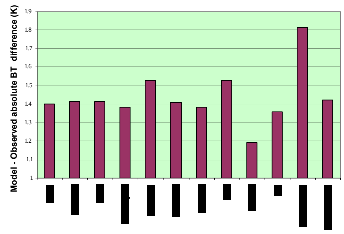

Figure 6: *Absolute mean difference between observed and simulated radiances averaged over all channels for each model for ARM site profile*

Comparisons with observed AIRS radiances were made for one profile over the tropical western Pacific ARM site as shown in **Figure 5** and summarised in **Figure 6**. SARTA shows best agreement with the AIRS observations and this is clear around AIRS channel 2150 (circled) which is due to the improved CO_2 R-branch line mixing formulation in kCARTA and also a new water vapour continuum. Hartcode, OSS and LBLRTM models are further from the observations (generally warmer at shorter wavelengths).

4. Comparison of layer to space transmittances and jacobians

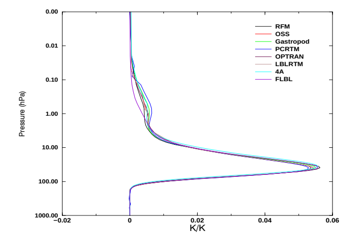

Figure 7: *Comparison of modelled temperature jacobians for profile 3 and AIRS channel 71*

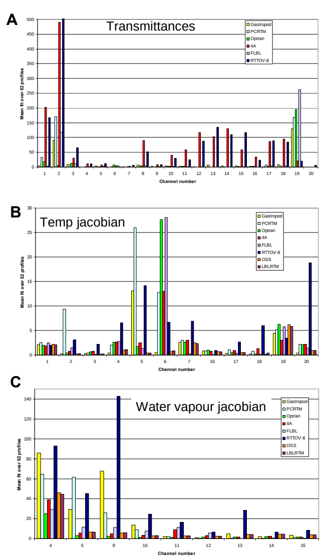

Figure 8: *Plots of averaged goodness of fit for 20 AIRS channels (in Table 1) for level to space transmittance (A), temperature (B) and water vapour (C) jacobians*

† RTTOV-7 and Sigma-IASI to be included in these plots

Profiles of surface to space transmittance and temperature, water vapour and ozone jacobians were computed by some of the RT models for the 52 profiles and a selection of 20 AIRS channels defined in **Table 1**. The channels were chosen with different peaks in their weighting functions for mixed gases, water vapour and ozone. An example of the jacobians computed is shown in **Figure 7**. For this profile, in general the models are in good agreement except between 0.1 and 5 hPa. In order to determine how closely the transmittances and jacobians fit to a reference profile, a 'goodness of fit' parameter M is used defined as:

$$M = 100 \times \sqrt{\frac{\sum (X_i - X_{ref})^2}{\sum (X_{ref})^2}}$$

where X_i is the profile variable at level *i and* X_{ref} is the reference profile which was taken to be the RFM model profile for this study. **Figures 8A–C** summarise the fit for transmittance profiles, temperature and water vapour jacobians for some of the models†. For transmittances RTTOV-8 and 4A differ most from RFM but only for some channels. For temperature jacobians the models have a similar performance for most channels, although for a few channels some models have a poorer fit. Channel 6 (787) seems particularly difficult to model. For the water vapour jacobians RTTOV-8 and to a lesser extent Gastropod and PCRTM have the worst fits to the RFM profiles. The poor fits are only from a few profiles.

Channel Number	AIRS channel	Frequency cm^{-1}	Jacobian
1	71	666.7	T
2	77	668.2	T
3	305	737.1	T
4	453	793.1	T, Q
5	672	871.2	T, Q
6	787	917.2	T
7	1021	1009.2	T, O_3
8	1090	1040.1	O_3
9	1142	1074.3	Q
10	1437	1323.8	Q
11	1449	1330.8	Q
12	1627	1427.1	Q
13	1766	1544.3	Q
14	1794	1563.5	Q
15	1812	1576.1	Q
16	1917	2229.3	T
17	1958	2268.7	T
18	1995	2305.5	T
19	2107	2385.9	T
20	2197	2500.3	T

Table 1: *List of AIRS channels used for transmittance and jacobian comparisons plotted in Figure 8*

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International TOVS Study Conference, 14th, ITSC-14, Beijing, China, 25-31 May 2005. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2005.