Comparison of radiative transfer models for AIRS

Why compare RT models?

- In data assimilation and retrieval applications it is important to understand the error characteristics of the forward model and its gradient (i.e. Jacobian).

- By comparing an ensemble of RT models with different methodology and based on different spectroscopy the spread of the differences can be an indication of the RT model error.

- Obvious ‘bugs’ in any of the models can also be identified during the comparison.
Compare RT models by:

- Compute Br. Temps for all 2378 channels for 52 diverse profiles
- For some models compute jacobians for a selection of 20 channels and 52 profiles
- For some models compute layer to space transmittances of 20 channels and 52 profiles
- Use RFM as reference RT model
## AIRS RT model Comparison

<table>
<thead>
<tr>
<th>Model</th>
<th>Participant</th>
<th>Direct</th>
<th>Jacobian</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTTOV-7</td>
<td>R. Saunders, METO</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>RTTOV-8</td>
<td>R. Saunders, METO</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Optran</td>
<td>Y. Han, NESDIS</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>OSS</td>
<td>J-L. Moncet, AER</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LBLRTM</td>
<td>J-L. Moncet, AER</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>RFM</td>
<td>N. Bormann, ECMWF</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Gastropod</td>
<td>V. Sherlock, NIWA</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ARTS</td>
<td>A. Von Engeln, Bremen</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>SARTA</td>
<td>S. Hannon, UMBC</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>PCRTM</td>
<td>Xu Liu, NASA</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4A</td>
<td>S. Heilliette, LMD</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>FLBL</td>
<td>D.S. Turner, MSC</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>σ-IASI</td>
<td>G. Masiello, IMAA-CNR</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hartcode</td>
<td>F. Miskolczi, NASA</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

+ other models being added
Diverse ERA-40 52 Profile set

All 52 profiles dynamically consistent with all 3 variables
Comparison of AIRS forward models

![Graph showing comparison of AIRS forward models](image)

- Br. Temp (degK)
- AIRS channel number

Models:
- RFM
- RTTOV-7
- ARTS
- FLBL
- Gastropod
- LBLRTM
- OPTRAN
- PCRTM
- OSS
- SARTA
- HARTCODE
- SIGMA-IASI
- RTTOV-8

Legend:
- CFCs
- w.v. continuum
Mean bias for all 49 diverse profiles

![Graph showing mean bias for different models against AIRS channel number. The graph includes various models such as RTTOV-7, ARTS, FLBL, LBLRTM, OPTRAN, PCRTM, OSS, SARTA, 4A, HARTCODE, SIGMA-IASI, and RTTOV-8. The y-axis represents the model bias in degrees Kelvin, while the x-axis represents the AIRS channel number.]
Model bias for different bands

Model-RFM for different spectral regions

St. dev (degK)

- 650-770 cm\(^{-1}\) chans 2-407 \(T\)
- 770-980 cm\(^{-1}\) chans 408-953 \(Sfc+Cld\)
- 1000-1070 cm\(^{-1}\) chans 1001-1133 \(Ozone\)
- 1250-1350 cm\(^{-1}\) chans 1328-1487 \(Q\)
- 2150-2250 cm\(^{-1}\) chans 1866-1939 \(T\)
- 2350-2420 cm\(^{-1}\) chans 2017-2142 \(T\)
- 2420-2600 cm\(^{-1}\) chans 2143-2318 \(Sfc\)
AIRS channels selected for jacobians
Comparison of Jacobians

Temperature jacobian
Profile 1 AIRS channel 77

Pressure (hPa) vs. K/K
Measure of fit

For the jacobians the results from each model were differenced with RFM one of the line-by-line models in order to be able to conveniently examine the inter-model differences. For the jacobians the “measure of fit” adopted by Garand et. al., [2001] was 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 variable which was taken to be the RFM model profile for this study.
Comparison of temperature jacobians
Comparison of water vapour jacobians

Model Key
1 OSS
2 Gastropod
3 CRTM
4 Optran
5 LBLRTM
6 RTTOV-8
7 FLBL
8 RTTOV-7
10 Sigma-IASI

Channel 4
Channel 5
Channel 9
Channel 10

Channel 11
Channel 12
Channel 13
Channel 14

Channel 15

Fit to RFM

Model number

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This is a weak temperature jacobian but some of the models (e.g. 4A, PCRTM) have very unphysical structures. Does this matter?

The measure of fit is not ideal for assessing these features.
Thanks any questions?

All results and some plots are on the ITWG web page at:

http://cimss.ssec.wisc.edu/itwg/groups/rtwg/rtairs.html

*Paper to appear in JGR soon*