

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Web site: www.cimss.wisc.edu/itwg/rtwg.html

Working Group members: R. Saunders (Co-Chair), L. Garand (Co-Chair) with F. Weng, M. Matricardi, P. Brunel, T. Kleespies, L. McMillin, J. Li, N. Jacquinet-Husson, D.S. Turner, V. Sherlock, G. Deblonde, C. Köpken, J. Grove-Rasmussen, H. Woolf, J-L. Moncet, M. Vesperini, C. Crevoisier, P. Schlüssel, D. Klaes, Y. Han, E. Weisz, M. Schwaerz, X. Wu, A. Uspensky, R. Knuteson, P. Wang, A. Dybbroe, A. Collard, T. Auligné, M. Szczech-Gajewska, D. Anselmo, L. Strow (provided inputs during ITSC-13).

This working group focuses on the issues related to atmospheric radiative transfer (RT) and surface property models which are relevant for radiance assimilation and atmospheric and surface retrievals from past, current and planned infrared and microwave sounder data.

2.1.1 Atmospheric profile datasets for Radiative Transfer

Radiative transfer (RT) models require a dataset of diverse profiles for training and independent validation. The group is actively using various profiles datasets whose characteristics are summarised in Table 2.1. A Fortran 90 code for interpolating a profile from one level to another and extrapolation above the top level has been provided to the group as an action from the last meeting. One of the developments since ITSC-12 has been the use of NWP model based profile datasets that have a more consistent treatment of humidity in the upper troposphere and lower stratosphere.

Action

Roger Saunders to post profile interpolation code on ITWG-RTWG web page.

Diverse Profile dataset	Number of profiles	Number of levels	Contact point/web page
TIGR v3 radiosonde set	2311	40L	Raymond Armante, LMD
Sub set from v2	43	43L	Marco Matricardi, ECMWF
ECMWF 60L model set	13495	60L	http://www.metoffice.com/research/interproj/nwpsaf/rtm/
Sub set	52	101L	
ECMWF 50L model set	13766	50L	Scott Hannon, UMBC
Sub set	117	43L	
UMBC set ¹	49	101L	Hal Woolf, CIMMS
	49	42L	
NOAA-88	8005	40L	Larry McMillin, NESDIS
Sub set	32	40L	
CIMSS	32	40/42/101 L	Hal Woolf, CIMMS
CIMSS Ozone	380	40L	Hal Woolf, CIMMS
Sub set	34	40L/43L	M. Matricardi for 43L
Trace gases CH ₄ ,CO,N ₂ O, CO ₂	43	90L	Marco Matricardi, ECMWF

¹One profile in the upper levels in the UMBC set has stratospheric temperatures that are too cold.

Table 2.1 Summary of diverse profile datasets used to train RT models

Recent developments include a consideration of the units conversion for water vapour. A report on this is available on request from Peter Rayer (peter.rayer@metoffice.com) at the Met Office

Action

Roger Saunders to put trace gas profiles on ITWG-RTWG web site.

2.1.2 Instrument characteristics required for RT modeling

The group reviewed where there were new requirements or gaps in the instrument data required for RT modelling. The following is a list of the new or existing sensors where the group recognized information is still required for accurate RT simulations:

- ATOVS filter responses for NOAA-N due for launch in Sep 2004

Action

Tom Kleespies to inform ITWG before NOAA-N launch.

- MTSAT IR channel characteristics are available from Jeff Puschell (Raytheon) subject to approval by JMA.
- AMSR-E Paul Van Delst (NCEP) has the channel responses.
- SSMIS channel characteristics are available. S/N02 is the sensor in orbit.

Action

Tom Kleespies to provide SSMIS channel characteristics.

- WINDSAT channel characteristics are required.

Action

Tom Kleespies to obtain and provide WINDSAT measured channel responses.

2.1.3 Line by Line (LbL) model status

The status of IR LbL models used by the group is summarized below:

- **GENLN2**: No new developments were reported. **RFM** is a faster more user friendly version of GENLN2 available from Oxford University.
- **kCARTA** has been updated based on AIRS validation. Code available on UMBC web site. (contact is Larrabee Strow at UMBC email: strow@umbc.edu).
- **LBLRTM**: A new version 8.2 is now available from AER web site at <http://rtweb.aer.com>
- **4A** in its operational version is now distributed by NOVELTIS but is still free for research groups. It uses GEISA-2001 at <http://ara.lmd.polytechnique.fr>
- **s-IASI** is available from EUMETSAT based on LBLRTM but optimised for IASI.
- **Hartcode** from R. Rizzi/F. Miskolczi
- **FLBL** from Shawn Turner (MSC) for research in MSC and used to train MSCFAST.

Recommendation

Infrared line by line models can now be validated using AIRS data with collocated profiles for a wide range of atmospheric situations. Model developers should be

encouraged to update their models and/or spectroscopic databases in the light of this new dataset.

For microwave LbL models:

- **MONORTM** is a simplified version of LBLRTM for the microwave and can be obtained from the same web site as LBLRTM.
- **MPM 89/92** continues to be used by many groups (i.e. basis for RTTOV and OPTRAN)
- **Rosenkranz** model last updated in 2002.
- **ATM** from Juan Pardo.
- **STRANSAC** from LMD.
- **ARTS** a model developed at Bremen University which is being extended to cover the infrared. A poster was presented on ARTS.

2.1.4 Assessment of spectroscopic databases

The performance of the new generation of high spectral resolution atmospheric sounders (e.g. AIRS, CrIS and IASI) is dependent upon the quality of the spectroscopic parameters of the active gases since these are used as input to the LbL models. The latest official releases for spectroscopic parameters are GEISA-2003 and HITRAN-2000+ and there is code available to convert from GEISA into HITRAN format. It was noted that there are plans to change the format of HITRAN in the future. A warning about the treatment of CFCs in HITRAN was discussed where all the negative absorption values have been suppressed. Nicole Jacquinet-Husson (LMD) reported on the draft of a 'road map' for the HITRAN and GEISA databases.

Action

Nicole Jacquinet-Husson to send Roger Saunders copy of 'road map' document for distribution to the group.

LMD have also continued support for the aerosol dataset for IASI.

The role of this group to help provide information through the web site of useful validation datasets (e.g. ground based, airborne, satellite) was proposed.

Action

All members of the group to send information on validation datasets to RTWG co-chairs for posting on the ITWG-RTWG web site on a new validation page.

2.1.5 Fast RT models

The working group noted the continuing progress on fast RT models, especially for simulating AIRS data. The group reviewed the status of fast models:

OPTRAN: Version 6 is available and is the operational code. Version 7 uses a corrected transmittance term in place of the effective transmittances. Version 8 is under development and uses a polynomial fit to represent the coefficients along the absorber path. The point of contact is Yong Han (NESDIS). Plans are to merge versions 7 and 8 and to use it for cloudy radiance

simulations. Other plans include additional variable gases. Papers on OPTRAN have been submitted to Applied Optics.

RTTOV: Version 7.1 is the latest version. Version 8 will be released in Feb 2004 and the paper in the proceedings by Saunders *et al.* gives more details. Users were reminded to feedback any problems to rttov.nwpsaf@metoffice.com. RTTOV-71 can simulate cloudy radiances.

GASTROPOD: An AIRS fast model based on kCARTA. This is an open source project and code can be downloaded from gastro.sourceforge.net. Regression coefficients for pre-launch and the latest post-launch AIRS ISRF are available.

OSS: The code is working for AIRS, CrIS, NAST-I, AMSU and CMIS. The training on LBLRTM and possibly kCARTA will be redone to include the CFCs. Cloudy radiance simulation is planned. The code may be available on request to Jean-Luc Moncet (AER).

MSCFAST: The code is being used at Met. Service Canada for GOES radiance assimilation. It also supports AIRS, but currently only the 324 channel subset.

LMD fast models: A Neural Net model has been developed for AIRS and IASI simulations. A jacobian model has also been developed for AIRS. A poster on the LMD fast models was presented at the conference. In addition, the 3R and 3R-NN models from LMD have demonstrated their capability in simulating TOVS channels (Chédin *et al.* JQSRT, **77**, 2003).

SARTA: AIRS fast RT model from UMBC based on kCARTA.

PLOD/PFAAST: Hal Woolf has developed code for HIRS, MODIS, GOES and other IR sensors. It is trained on the UMBC 48 profiles with LBLRTM. Plans are to update with cleaned up training set and latest version of LBLRTM.

RTIASI: Fast RT model for simulating IASI radiances. Version 4 is available from EUMETSAT with variable trace gases and reflected solar radiation. Version 5 will be released in June 2005 with scattering, aerosols and clouds.

Issues for fast models

- Trace gases

Fast models are now beginning to have the capability to treat trace gases as variable in the same way as water vapour and ozone have been in the past. This allows retrievals of trace gas concentrations. However a trace gas climatology is still required for retrievals which require a climatological first guess. The models should have the ability not to compute trace gas transmittances if they are not required.

- Number of levels and predictors

Increasing the number of layers for fast models may be required for advanced sounders but it also slows the model run times for ATOVS. Fast models need to be flexible to allow different number of levels for different sensors as required. Increasing the number of predictors for higher accuracies needs to be balanced against the increased model run times. It was thought 40-50 levels is enough for ATOVS but ~90 levels may be needed for AIRS simulations.

- Broad channels

Broad band channels can be difficult to simulate with fast models as one central frequency is not a good approximation for the whole channel. Planck weighted transmittances have been used in the past (e.g. Weinreb and Hill, *NOAA Technical Report NESS 80*, 1980) with some success and more recently with RTTOV (see poster at ITSC-13 by Pascal Brunel and Shawn Turner). Also a Planck function correction which uses the central frequency as a free parameter rather than setting it to the mean value can extend the range over the usual 2 parameter (band correction factors) solution.

- Model diagnostics

Several users asked for the option to be able to output profile layer mean quantities which were used in the regression. Outputting the various emission terms (surface, upwelling, downwelling) was also requested.

- Fast model testing for Tangent Linear and Adjoint codes.

This is an area where it was felt some guidance to the users is required. Both Tom Kleespies and Paul VanDelst have some lecture notes on TL/AD testing. They made the point each module should be tested individually. Vanessa Sherlock noted inner products could be used to test tangent linear and adjoint codes.

Action

Tom Kleespies and Roger Saunders to collect notes on this topic and post a summary on the ITWG-RTWG web site.

2.1.6 AIRS RT model comparison

At the workshop for Soundings from High Spectral Resolution Observations in May 2003 an AIRS radiative transfer model comparison was proposed and Roger Saunders is now co-ordinating this activity under the auspices of the ITWG. Results from 9 models have already been submitted and about 15 participants have indicated they will provide results. An initial analysis of the differences was presented as a poster at ITSC-13. It was emphasised the importance of having results from the LbL model dependent set for each of the fast models so that the difference between the LbL models can be excluded from the analysis. Error correlations from the model differences were also requested to be documented in the results. Larabee Strow offered to provide profiles from the ARM W. Pacific site, together with AIRS data to provide a comparison between the models and measurements. The method of Louis Garand will be adopted to assess the Jacobian differences. A reference jacobian will have to be selected which

could be the dependent set, where possible, for each fast model. It was agreed any comparison of model run times (e.g. for 1000 profiles) would only be approximate but it was felt this was still useful information. To summarise the aim of the first phase is:

- To compare the forward model calculations for all the AIRS channels from all the models for 52 diverse profiles and one tropical Pacific profile coincident with AIRS data.
- To estimate model error covariances.
- Assess the jacobians from each model using the Garand measure of fit for a limited selection of channels.
- Document the time taken to run each model.

The plan is to have all the results submitted by Jan 2004 and provide a report by April 2004. The results would be posted on the web site at:

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

As a second phase it was suggested to provide a line by line transmittance dataset to all participants for training so the uncertainties due to the different profiles and spectroscopy could be eliminated. However data volumes may make this difficult to achieve at least for all the AIRS channels. It was also suggested to do studies on the impacts on AIRS retrievals of the RT model errors derived from phase one. Vanessa Sherlock will address this by assessing how the RT errors feed through to the retrievals using a 1D-Var code. The response of the models to surface emissivity was also a parameter of interest which may be added.

Recommendation

All AIRS RT modellers should be encouraged to participate in the AIRS RT model comparison to assist in the estimation of forward model error covariances.

Action

Roger Saunders to obtain profiles and AIRS data from Larrabee Strow and provide to modellers.

2.1.7 Surface Property Models

2.1.7.1 Microwave emissivity

Ocean surface

FASTEM-2 is being updated by Stephen English (Met Office) to improve the simulations and add a polarimetric capability so all 4 components of the Stokes vector are computed. It will be released as part of RTTOV-8.

NRL is developing a polarimetric model for WINDSAT.

Paul Chang at NESDIS is preparing a field campaign during 2004 to make microwave sea surface measurements at high wind speeds to validate the models.

Land surface

A new snow model by Fuzhong Weng (NESDIS) will soon be tested on AMSU channels. Stephen English presented results showing that data assimilation trials using the microwave surface emissivity atlas had not been successful suggesting an implicit retrieval of surface emissivity might be more successful.

2.1.7.2 Infrared emissivity

Ocean surface

The sea surface emissivity model from Wu and Smith (*Applied Optics*, 36, 1997) is now being used for developing fast IR surface emissivity models (e.g. at NCEP) due to the more complex treatment for larger viewing angles and higher windspeeds although their results agree with Masuda *et. al.* for normal windspeeds and close to nadir view angles.

For RTIASI an alternative to the Cox and Munk slope variance for the ocean surface has been developed using a surface wave model in an attempt to provide more realistic computations of reflected downwelling radiation. This allows the emissivity model to be initialised by a wave model in an NWP system. Shaw and Churnside (*Applied Optics*, 36, 1997) have published measured statistics of sea-surface slope. In the era of advanced sounders it would be worth updating the IR sea surface emissivity models with newer datasets.

Land surface

Several talks were presented during the conference on this topic. There are now several MODIS atlases of land surface emissivity and in a few years there will be global atlases of surface emissivity in all the AIRS window channels. Retrievals of surface emissivity have been demonstrated from AIRS over the ARM Oklahoma site. There is a University of Washington study making measurements over snow. The current efforts in NWP centres to use more IR radiances over land should encourage more research into land surface emissivity.

2.1.8 Review of group web page

The web pages will be updated to include the new information provided during ITSC-13.

Action

Co Chairs to update web pages and ITWG-RTWG to propose additions and improvements.