Lorne March 2002 Report

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Working Group members: R. Saunders (Co-Chair), L. Garand (Co-Chair) with S. Gu, F. Weng, M. Matricardi, P. Van Delst, P. Brunel, T. Kleespies, F. Chevallier, L. McMillin, J. Li, N. Jacquinet-Husson, S. Turner, R. Armante, T.R. Sreerekha,V. Sherlock, S English, G. Deblonde, C. Köpken and input from F. Prata and M. Goldberg.

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 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 datasets summarised here. Recent developments include the generation of the TIGR-2000 dataset at LMD, which has 2311 profiles of temperature, humidity and ozone, the latter coming from the UGAMP dataset. Humidity is extrapolated above 300 hPa. The ECMWF profile set selected from the 60 level model analyses with fully analysed ozone consistent with the temperature and humidity fields is now available. There are 13,000 profiles on model levels with a subset of 80 selected profiles also available for RT model training. In addition to temperature, humidity and ozone there are cloud and surface variables from the model also included with each profile. This dataset is available from the RTTOV web site at: http://www.metoffice.com/research/interproj/nwpsaf/rtm

Other datasets in use are the 48 profiles from the University of Maryland Baltimore County, which are a mix of AFGL, TIGR, and NOAA profiles (contact Scott Hannon, UMBC); the Garand intercomparison set of 42 profiles selected from a larger database which uses SAGE data for upper water and ozone (contact Shawn Turner, MSC). The NOAA-88 profiles that include rocketsondes and SBUV ozone are available from Mitch Goldberg (NESDIS) and there are several versions.The older 43L TIGR-2 dataset (43 water vapour profiles) and the NOAA-88 set (34 ozone profiles) are used for RTTOV and the original 42L 32 profiles from NOAA-88 are also still in use.

The group discussed the number of levels of the profiles required for advanced IR sounder simulations. It was agreed that around 90 levels are optimum based on studies at ECMWF and the Met Office since the last meeting. However it was also felt important to agree on a standard set of levels for everybody as the line by line (LbL) transmittance calculations are so expensive. This could be the AIRS 101 levels as this would allow a sub-sampling or interpolation to any required levels for RT training.

Recommendation: The next definitive LbL transmittance computation for fast RT model training should be on the AIRS 101 levels to facilitate use by all users.

The group noted that diverse profile datasets of trace gases (i.e. CO, CH_4, N_2O, CO_2) are now in preparation at ECMWF and being used for trace gas simulations. The issue of how many profiles are needed to train a statistical regression fast RT model was raised and the general consensus was about 50 profiles are the minimum number required. The representativity of a profile set was discussed. If the RT model can reproduce results with an independent profile set to an accuracy close to that for the dependent set then it is a reasonable assumption the dependent set is adequate. Members of the group reported problems consistently interpolating profiles on to different levels. There is a potential ambiguity relating layer integrated and level point values. Transmittance datasets should include documentation of any interpolation/integration routines so data can be used consistently.

Recommendation: A standard set of interpolation routines should be provided to optimally convert from level to layers (and vice versa).

The extrapolation of profiles to below the surface (e.g. for Antarctic profiles) was not recommended so that for training RT models the lower levels may have fewer profiles in the regression than the upper levels.

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 RT simulations:

- HIRS and AVHRR filter responses for NOAA-M due for launch in mid 2002.
    - **Action Tom Kleespies to inform ITWG before NOAA-M launch**
- The AIRS channel responses will be updated 6 months after launch. L. Strow (UMBC) will make the updates available.
- GOES imager filter responses are on a NOAA web site (except for GOES-9). Problems noted with GOES-12 should be documented.
    - **Action Pascal Brunel to contact Tim Schmidt (CIMSS) to clarify missing GOES data**
- MODIS responses for AQUA are needed
    - **Action Paul Menzel to provide contact point.**
- Concerns were raised about the lack of detail in the early METEOSAT filter responses.
    - **Action Roger Saunders to raise with EUMETSAT.**
- SSMI(S) channel characteristics are documented by Barbara Burns provided after the last ITWG. Roger Saunders can distribute to ITWG on request.
- For IASI simulations note a minor change in the definition of level 1C radiances has been made (contact Marco Matricardi for details)
- AMSR and WINDSAT channel characteristics are required.
    - **Action Fuzhong Weng to inform group of any information**

Recommendation: **That instrument builders provide response functions in digital form and at the actual spectral resolution it was measured.**

Recommendation: **That RT modellers document clearly which filter responses were used in their simulations (e.g. by including them in the output files).**

NOAA have recently moved to using the latest set of fundamental constants in their processing. It was emphasized that the same set should be used in the calibration processing as in the RT model simulations.

Action: **Tom Kleespies to announce the new NOAA set of fundamental constants to group.**

2.1.3 Line by Line (LbL) model status

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

- GENLN2/GENLN3: new release planned but no new science, just more user friendly and Fortran 90 (contact is Dave Edwards at NCAR email:edwards@ncar.ucar.edu)

- kCARTA is being used for AIRS simulations (contact is L. Strow at UMBC email: strow@umbc.edu).

- LBLRTM: Version 6.01 is available. Some of the new features are:

  - Capability to input atmospheric profile on either altitude or pressure grid, and to output quantities on either altitude or pressure grid.
  - Capability to compute quantities for atmospheric layers which are not in local thermodynamic equilibrium (non-LTE option).
  - Update of universal constants
  - Contact is clough@aer.com

- 4A-2000: Various improvements have been made since the last meeting to be reported in a paper (contact is N. Scott at LMD email: scott@ara01.polytechnique.fr).

A report has recently been published documenting the EUMETSAT sponsored intercomparison of line by line models for IASI simulations. It is available at:
http://www.eumetsat.de/en/area2/publications/tm08.pdf
The results of this study, at least for the two airmasses considered, can be used to identify parts of the infrared spectrum where model and/or spectroscopic errors are significant.

Recommendation: The EUMETSAT Line by Line intercomparison is a valuable attempt to document biases in LbL models. It should be extended to more airmass types.

For microwave LbL models:

- MPM 89/92 is used by many groups (i.e. basis for RTTOV and OPTRAN) (contact: Roger Saunders)
- MPM 97: includes updated 23.8 GHz band used at NOAA. (contact: Fuzhong Weng)
- Rosenkranz 1997: updated with a band model used at NOAA. (contact: Fuzhong Weng)

- ARTS a new model developed at Bremen Univ. which aims to be a reference model (contact: Sreerekha Ravindranathan)

There are still biases between measurements and models around the 23 GHz water vapour line. It was noted there are plans for microwave sounders at frequencies up to 500 GHz and so models will need to be able to simulate radiances at these sub-millimeter wavelengths.

Actions:

Sreerekha Ravindranathan to provide web site on new microwave RT model inter-comparison work at Bremen Univ.

Raymond Armante to provide information to group on the STRANSAC-2000 study on microwave simulations.

2.1.4 Assessment of spectroscopic databases

The performance of the new generation of high spectral resolution nadir view 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-2000 and HITRAN-2000. Nicole Jacquinet-Husson (LMD) reported on significant efforts to improve the spectroscopy for advanced IR sounders like IASI and AIRS. She commented on the development of the GEISA/IASI spectroscopic database which is an extract, in the IASI and AIRS spectral range (600-3000 cm^{-1}), and a partial update of GEISA. This work is ongoing within the ISSWG (IASI- Infrared Atmospheric Sounding Interferometer- Sounding Science Working Group), and funded by CNES/France, EUMETSAT and the E.C. Environment and Climate Program. These efforts are associated with an international collaboration for IASI required spectroscopy, notably trace gases. The current edition of GEISA is accessible freely via the ARA/LMD group web site, upon prior request for password at *nicole.jacquinet@lmd.polytechnique.fr* The GEISA/IASI spectroscopic database is available at: ftp://ara01.lmd.polytechnique.fr/pub/geisa/iasi2000 (anonymous ftp). An updated HITRAN-2000 database is available. The updates are documented at http://www.hitran.com/hitran/updates.html For the water vapour continuum, CKD 2.4, is the new standard. The EUMETSAT LbL comparison mentioned above is part of the assessment of the accuracy of these datasets.

2.1.5 Fast RT models

Status of fast models:

OPTRAN: Adapted to AIRS. Work underway to improve ozone channel simulations (see papers by McMillin, Kleespies and Van Delst in this conference proceedings).

RTTOV: Version 7 about to be released which includes AIRS and SSMI(S) simulation capability. Details in paper by Saunders et al. (this conference proceedings).

GASTROPOD: Fixed pressure level model for AIRS (see paper by Sherlock et. al. in this conference proceedings).

OSS: Proprietary code developed by AER for CrIS but not yet available to RT community. Is reported to be fast and accurate. The group encouraged AER to include the IR model in the Garand comparison. Contact is Jean-Luc Moncet at AER.

MSCFAST: Implemented at MSC for use in GOES radiance assimilation. Will be adapted to AIRS. (contact Louis Garand).

3R-N: This fast model is based on neural networks and has been developed for TOVS channels at LMD (contact Raymond Armand).

Issues for fast RT models:

- Statistical models

Progress has been made on water vapour and ozone simulations for constant pressure models which for ATOVS channels now give errors well below the instrument noise. Developments are under way for other trace gases to be treated in these models. Water vapour continuum should also be treated as a separate gas from the line absorption to facilitate updates separately from the line datasets. The robustness of the simulations and proper weighting of the predictors requires further investigation. For example, channels in the center of strong lines can be difficult to simulate.

- Physical models

Updating of MSCFAST to AIRS will allow a detailed investigation of the errors versus wavelength for narrow channels. It should be noted that at least one fast physical model has been developed for MW applications (FASMPORT, Weng et al, to appear in *JAS*). This is a polarimetric 2-stream model for SSM/I, SSMI(S) and WINDSAT.

- Neural networks

The performance of these models for forward calculations is promising in terms of speed and accuracy. These models still need to be proven for Jacobian computations.

- Clouds and precipitation

Developments have been made to include cloud in fast radiance simulations. This will serve not only for NWP model validation, but also for research in the assimilation of cloudy radiances (see Chevallier et al this conference). More work is needed to include precipitation effects in fast RT models.

- 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. RTTOV for instance has errors of almost 2 K for the SEVIRI 3.9 micron channel due to this effect.

- Interferometer channels

These can have negative lobes and so have to be treated correctly for simulation. Currently only apodised radiances with very small negative side lobes have been simulated but work is planned to simulate unapodised IASI radiances.

- RT model biases

An improved understanding of RT model biases as shown by the Garand intercomparison is required. For the use of RT models in NWP data assimilation models it was noted they should be the same in both the global and regional model of each NWP centre but that different bias tuning may be required for each.

Action: The web site maintained by MSC on the fast model intercomparison is a valuable resource for fast model development and should be maintained at least until the next ITWG meeting. Louis Garand.

Recommendation: The RT community is encouraged to continue to develop and improve fast models for new and existing sensors. It must be recognized however that NWP centers prefer to only have one RT model for all sensors in their assimilation code so new developments should be able to feed through to existing RT models in NWP Centres.

2.1.6 Surface Property Models

2.1.6.1 Microwave emissivity

Ocean surface
For ocean surfaces improvements in FASTEM have been made since the last meeting and this has been integrated in RTTOV-7 (see paper on FASTEM-2 evaluation at: http://www.metoffice.com/research/interproj/nwpsaf/rtm/rtm_reports.html for more details). A two scale model is under development at NESDIS by Fuzhing Weng and will be delivered to NCEP for future polarimetric sensors.

Land surface
At NESDIS the MEM (microwave emission model) has been developed and used in NCEP models. This has allowed more microwave radiances to pass the quality control tests in the assimilation. There are still problems with modeling the emissivity over melting sea-ice, multi-year snow and high topography and more work is planned at NESDIS. Work is underway at Bremen University and Sreerekha Ravindranathan will report back to the group on this work.

Action: Sreerekha Ravindranathan to report to group on work on surface models at Bremen.

2.1.6.2 Infrared emissivity

Ocean surface
For the ocean surface no major developments have been made since the last ITWG. Masuda parametrisations are used at several centers (i.e. ECMWF, NCEP) and ISEM-6 (within RTTOV) which is based on Masuda (1988) and Watts et al. (1996)

Issues:

- Accuracy for large viewing angles (>60 deg) required for geostationary radiance assimilation
- Accuracy for high wind speeds. Ship borne interferometer datasets are now available for model validation from Univ. Madison (contact P. Van Delst) and Univ. Miami (contact: pminnett@rsmas.miami.edu).

Land surface
For the land surface some work is underway in order to extend the use of radiance assimilation over land. However this is a difficult problem to reduce the errors to a point where lower peaking channels can be used over land. More channels with only a small sensitivity to the land surface may be able to be assimilated with an improved representation of the land surface emissivity in NWP models.

Issues:

- The link between spectral emissivity resolution and horizontal spatial resolution is important. When averaged over large areas for satellite ifovs the spectral emissivity variation is smoothed making it difficult to use lab and/or in situ measured emissivities without appropriate smoothing.
- Emissivity mixing is *not* linear, the temperature of each element also needs to be accounted for. At night the mixing should be more linear as the temperature contrasts are reduced.
- The emissivity can vary with viewing angle particularly for bare surfaces and uniform grassland.
- Validation is important for land surface emissivity datasets developed. There are several datasets with spectral emissivities measured over different surface types (e.g. see paper by M. Lynch in this conference). In addition MODIS data is being used to improve our knowledge of the IR emissivity.

Fred Prata (CSIRO) has drafted a note on issues for surface temperature and emissivity retrieval from satellite sounders.

Action: Roger Saunders to circulate a copy of the note to the group.

2.1.7 Proposal for group web page

It was proposed the working group web page should contain:

- Contact details of WG co-chairs

Links to:

- WG reports, ITSC-XI, ITSC-XII, …
- Links to instrument characteristics for RT calculations
- Links to Line by Line model pages
- Links to fast RT model pages
- Links to surface property models
- Links to fundamental constants
- Links to relevant reports/papers

Action: Co-chairs to prepare a web page for the WG
Action: All WG members to provide links to co-chairs which can be included on web pages