

# Budapest September 2000 report

## 2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

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This is a new working group set up to focus on the issues related to atmospheric radiative transfer (RT) and surface property models which are relevant for radiance assimilation and retrievals from sounder data. The technical sub-group on fast RT models was amalgamated with this group.

### 2.1.1 Review of RT Model Intercomparison

One of the recommendations from the ITSC-X meeting of the technical sub-group on fast RT models was a fast model intercomparison of ATOVS channels (sec 3.4.4 of the ITSC-X report). This followed on from the successful comparison of HIRS-12 radiances carried out by B. Soden under the GEWEX water vapour project (GVaP) and was published in BAMS. L. Garand has co-ordinated this new study with 29 models compared, some line-by-line (LBL) some fast models for a subset of 7 HIRS and 4 AMSU channels. Not only were the forward model brightness temperatures compared but also the Jacobians (analytical or brute force) for the radiances with respect to temperature, water vapour and ozone. The results were presented to the ITWG at the ITSC-XI meeting. The ITWG thanked L. Garand for this extremely valuable study which will benefit all fast RT model developers and users. The main conclusions were:

- IR LBL models typically agree to within 0.1 K, but up to 0.2 K (standard deviation) for some channels such as HIRS-12. Some differences (up to 0.6 K) still exist, some systematic (HIRS-5), others with a dependence on air-mass. It is recommended that differences in excess of 0.15 K be studied.
- No IR fast model reaches the desired accuracy of 0.25 K in all channels but that accuracy is achieved by at least one model in all channels. Largest differences are seen in water vapour channels. The amplitude and sign of the differences are often a function of the type of air mass. Fast models need to be tuned in some way to an accurate LBL reference. Using a less accurate narrow-band model (such as Modtran) for that purpose is not recommended.
- The Jacobian study revealed subtle forward model errors which otherwise were difficult to detect. Secondly, it provided clues on the cause of differences. It was observed that models which appear accurate for brightness temperatures (BT) may still have deficiencies in their Jacobians. It is believed this is the first dataset of LBL Jacobians against which fast models can be compared.
- Fast IR models which use a physical formulation of transmittances (as opposed to regression) appear promising. At the moment no attempt has been made to develop a fast physical MW model.

- MW fast modeling appears to be relatively easy with accuracies of 0.1 K or better obtained against the LBL used to develop the fast model. The main issue in microwave modeling is that significant differences among LBL models were found.
- Both LBL and fast models were corrected as a result of this intercomparison. Since errors were not obvious to the same degree in all channels, the variety of analysed channels was important.

**Actions:**

- L. Garand (MSC) to submit the draft report to a refereed journal summarizing the intercomparison (24 co-authors)**
- D. S. Turner (MSC) should make available the more specific report on IR LBL intercomparison to all members of working group after completion of internal review**
- L. Garand (MSC) will maintain the web site on the intercomparison until the next ITSC (from which atmospheric profiles and all model results can be downloaded).**

### **2.1.2 Diverse profiles**

Radiative transfer models require a dataset of diverse profiles for coefficient generation and independent validation. Several radiosonde based datasets exist (e.g. NOAA-88, TIGR-3) supplemented with UARS data above the radiosonde measurements. F. Chevallier (ECMWF) presented plans to generate a dataset of 2 million diverse profiles from the 60 level ECMWF forecast model analysed fields for temperature, water vapour and ozone. The working group encouraged this activity but made the following comments:

- The top level of this dataset will be at 0.1hPa. For some channels this is not high enough and so there is still a need to extend the profiles above this level. UARS data may be of use for this. L. McMillin reported that rocket sonde and SBUV data had been added to the NOAA-88 profile dataset. B. Burns also informed the group that she has a dataset which may provide some idea of the temperature variability at these low pressures.
- It was agreed that profiles with low surface pressures (e.g. over Antarctica) should still be included in the dataset so long as there were no more than 10% in the dataset and the profile is still extrapolated to the maximum pressure.
- The WG recommended that about 80 profiles are sufficient for creating the LBL transmittance datasets from which the fast model coefficients for fixed gases, water vapour and ozone are computed, however more may be required for minor gases.
- Diverse profile datasets of variable minor gases (e.g. CH<sub>4</sub>, CO, N<sub>2</sub>O, CO<sub>2</sub>) should also be generated soon to allow the new advanced IR sounders to retrieve their profile concentrations and also to improve the retrieval of temperature, water vapour and ozone.

**Actions:**

- a) **F. Chevallier (ECMWF) to inform the ITWG when the 60 level water vapour/ozone profile dataset is available.**
- b) **R. Saunders (UKMO)/M. Matricardi (ECMWF) to make available to the ITWG the 117 profile GENLN2/LIEBE transmittance dataset for independent validation of fast RT models for ATOVS and IASI.**

### **2.1.3 Instrument characteristics required for RT modeling**

T. Kleespies reported to the group that comparing RT model results using the NOAA 15 AMSU-A1 specified band pass filters with the actual measured values gave differences of greater than 0.1K for AMSU channels 12 and 14. The corresponding NOAA-16 differences were smaller indicating the AMSU-A1 instrument on this satellite is closer to the specified band pass filters. A poster presented at ITSC-XI by B. Burns also showed differences in simulated radiances for the SSM/I(S) instrument as specified and as measured. Information on the AMSR-E bandpass filters were requested from NASA.

There was some discussion on which recommended values of the fundamental physical constants to use in both instrument calibration and RT models. The latest (1998) values are at: <http://physics.nist.gov/cuu/Constants/>. T. Kleespies reported that he had found no significant differences between the latest values and the 1986 values in terms of RT model calculations.

The WG was also tasked by CGMS to report on the quantification of the required accuracy for spectral response specifications to reduce errors in the forward modelling of satellite radiances. The WG recommended:

#### **Recommendation:**

**Space agencies should measure and characterise the total system spectral response of future IR and MW radiometers, spectrometers and interferometers to an accuracy that changes in modelled radiances due to uncertainties in the response are well below the instrument noise.**

#### **Actions:**

- a) **T. Kleespies (NESDIS) to put AMSU band pass filter frequency characteristics in Annex D of the NOAA-KLM users guide and to provide link to M. Chalfant's web site for more detailed HIRS filter responses.**
- b) **T. Kleespies (NESDIS) to investigate if AMSU-A band pass filter shapes are available and if they are to investigate their impact on the measured radiances.**
- c) **T. Kleespies (NESDIS) to provide 'one stop' page giving links to sites for NOAA instrument characteristics.**
- d) **B. Burns (Aerojet) to make available the SSM-I(S) band pass filter characteristics to the ITWG.**

### **2.1.4 LBL model status**

An intercomparison of 12 IR LBL models (some runs of the same model at different centres) was carried out by the IASI Science Sounder Working Group co-ordinated by S. Tjemkes (EUMETSAT). The study focused on high spectral resolution channels by simulating IASI

spectra for model and real atmospheres. The latter have co-incident aircraft or ground-based interferometer measurements which the simulated spectra can be compared with. A report on the results will be presented shortly.

It was reported the most recent water vapour continuum correction is CKD version 2.4. New versions of the spectral line databases (HITRAN and GEISA) are about to be released in the coming year and will include enhancements such as the improved water vapour line parameters. The 4A and kCARTA approach is being more widely adopted as a way to efficiently store the LBL transmittances.

**Action:**

**R. Saunders (UKMO) to make available IASI LBL intercomparison report to ITWG.**

**Recommendations:**

**All centres creating LBL model transmittance datasets to co-ordinate activities with other centres to enable as wide a possible use of these datasets which are expensive to create.**

### **2.1.5 Fast RT model status**

The current status of the fast RT models was reviewed by the group:

- **RTTOV-6:** It is now adapted to support simulations for many instruments (i.e. ATOVS, SSM/I, TMI, MVIRI/SEVIRI, GOES (imager and sounder) and AVHRR). It includes cloud water in MW and the simulation of AMSU-B water vapour channel transmittances has been significantly improved.
- **OPTRAN:** Supports ATOVS, AVHRR, SSM/T, SSM/T-2, GOES (imager/sounder), GMS, and MVIRI. Two versions are now being developed one for optimal use within the NCEP model and one for more general use outside the model.
- **PLOD/PFAAST:** used with success for AIRS simulations. No analytical Jacobian routines available. PLOD is based on LBLRTM and PFAAST on kCARTA.
- **MSC-FAST:** Physical model adapted to a limited number of NOAA and GOES platforms. Allows cloud layers and analytical Jacobian. Specific transmittances for all gases. Operates on any vertical coordinate.
- For AIRS and IASI simulations, **PFAAST**, **OPTRAN** and **RTIASI** are under development and for CrIS a fast model developed by AER (**OSS**) with analytic Jacobians is being used.

### **Recommended areas for fast RT model future developments**

- **Improve accuracy of water vapour and ozone transmittance and Jacobian simulations**
- **Include solar reflection term in IR models**
- **Improve representation of surface scattering in models**
- **Pursue work on neural networks (noting difficulty is obtaining accurate Jacobians).**
- **Pursue development of fast physical models**
- **For newly developed ATOVS fast models a comparison with the Garand dataset should be made**
- **Extend model capabilities to include aerosols, clouds (liquid and ice) and precipitation**

- **Fast models should have a specific transmittance for all variable gases, including CO<sub>2</sub> and the water vapour continuum.**
- **More work on how to combine gas transmittances such that the product of individual transmittances equals the total transmittance is recommended as with more variable gases it will be more complex to combine transmittance ratios.**
- **Future intercomparisons should be able to compare each variable gas transmittance in order to better understand the cause of differences.**
- **The optimal number of levels (pressure or absorber space) for advanced sounder RT models should be investigated**
- **Fast RT models for advanced sounders should be further optimised to allow a flexible combination of channels and/or ‘super channels’ to be computed fast enough to allow real time data assimilation of >200 channels for every AMSU-A fov.**

## **2.1.6 Surface Property Models**

### **2.1.6.1 Microwave emissivity**

For land surfaces dynamically updated maps of surface emissivity are now available from the NESDIS web site ([http://orbit18i.nesdis.noaa.gov/html/day2\\_datatab.html](http://orbit18i.nesdis.noaa.gov/html/day2_datatab.html)) for AMSU channels 1-3. Modelling surface emissivity at higher frequencies is more problematic. Better scattering models are required above 10 GHz. The use of the AVHRR NDVI product may be a useful input to the models. The Southern Great Plains project may provide some useful validation of these models.

For the sea surface, FASTEM2 and the Hollinger model have been developed for AMSU and the model from L. Phalippou is used for SSM/I. Attempts are being made to unify these models for both instruments. Uncertainties in the Bragg scattering and foam cover exist for windspeeds above 7 m/s. Polarmetric emissivity models are now under development although they are semi-empirical.

#### **Recommendations:**

- **Compute a dry land surface emissivity atlas and then convolve with the water amount based on river/lake area and perhaps later recent precipitation from the model**
- **Compare the various emissivity atlases now being produced to identify where there are significant differences between them.**
- **Encourage the various efforts for developing better land and sea surface models which are not specific to one instrument only.**
- **Aircraft measurements of microwave surface emissivity are required over land and over sea for higher windspeeds.**
- **Physical polarmetric emissivity models for future instruments should be developed.**

### **2.1.6.2 Infrared surface emissivity**

The Masuda model has been parameterised by several groups for use with fast RT models some which include a wind speed dependence and others not. For high windspeeds (>5 m/s) and large zenith angles uncertainties still exist and so as with the microwave models more validation measurements are required for high wind speeds.

**Action:**

**R. Saunders (UKMO) and P. Van Delst (NESDIS) to investigate if ship interferometer data exists for high surface wind speeds.**

Datasets exist of measured surface emissivity for a variety of different land surface types and is available as an ASTER CDROM ( <http://speclib.jpl.nasa.gov/> ) The CERES dataset of a 10 arc minute atlas of surface type is also available at ([http://tanalo.larc.nasa.gov:8080/surf\\_htmls/SARB\\_surf.html](http://tanalo.larc.nasa.gov:8080/surf_htmls/SARB_surf.html)). As with the microwave the recommendation to compute a dry surface emissivity above is equally applicable to the IR. MODIS data may also contribute in defining the atlas of surface types necessary for this work. Some limited surface emissivity measurements are available (e.g. down looking AERI).

**Recommendations:**

- **Develop fast IR surface emissivity models (codes) for generic land surface types**
- **Measurements of IR surface emissivity are required over land and over sea for higher windspeeds.**