2. WORKING GROUP REPORTS

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING
Web site: https://groups.ssec.wisc.edu/groups/itwg/rtsp

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2.1.1 Line by Line Modeling
The RTSP-WG discussed the improvement of LBL calculations using an enhanced formulation of CO_2 line mixing effects (e.g. full line mixing) and the introduction of a speed dependent formulation of the Voigt line shape. It was noted that full line mixing is worth pursuing at 15 µm whereas first-order line mixing is sufficient at 4.3 µm. At shorter wavelengths, first-order line mixing is still sufficient but requires speed dependent Voigt and Dicke effects to be included. The full impact of Voigt line shape is yet to be studied in the thermal infrared. It was also noted that in the MW, speed dependent effects and second-order line mixing have a not negligible impact.

Recommendation RTSP-1 to LBL model developers
    Include full line mixing and speed dependent Voigt line shape when relevant.

Action RTSP-1 to Sergio DeSouza-Machado
    Report on the development of the Harvard CO_2 line mixing model especially with regard to possible issues related to full line mixing calculations around ~730 cm-1 and negative optical depths in first-order line mixing calculations.

The group discussed the status of CLBLM and noted that the model has not yet been officially released. Doubts were raised regarding the funding of the project. University of Colorado is developing a new LBL model mainly for radiation scheme applications. It was also noted that there is a need for the characterization of LBL model error covariances which could be useful for use in NWP applications.

Recommendation RTSP-2 to LBL model users
    To share LBLRTM input file (TAPE5) generation processors (perhaps having a discussion group online for sharing).

Action RTSP-2 to the group
    Report on the development/availability of LBL model error covariance datasets, especially those including high water vapour loading situations. Need to review the work of Cimini et al., LBL error covariance and spectroscopic parameter perturbation in the MW available in several publications.

2.1.2 Spectroscopy

The group discussed the need of a spectroscopic characterization of the impact on TOA radiances. This should be based on the use of known uncertainties in spectroscopic parameters such as the line shapes, line strengths, and half widths. Uncertainties in line shapes should also include line mixing. It was also noted that the possibility exists for using spectroscopic parameters that allow computing line broadening effects due to specific species.

Recommendation RTSP-3 to the group
    Report and/or suggest specific studies/methodologies used for spectroscopic error propagation.

Recommendation RTSP-4 to LBL model users
    For terrestrial applications, when available, include in the LBL calculations the effect of CO2 line broadening by water vapour.

Action RTSP-3 to Sergio DeSouza-Machado
    Communicate to the group results of the study on spectroscopic parameter perturbation effects on radiances.

2.1.3 Fast RT models in the near IR, Visible and UV. NLTE effects in the near

The group discussed the development of fast RT models in the near IR, visible and UV. In the visible, LUT based models are well established (e.g., MFASIS) but it was noted that physically based models (e.g., FLOATSAM) are also available. Recent MFASIS developments based of the use of a NN approach for LUTs were discussed. Alternative approaches including a fully based AI/ML model and a Principal Component based model were noted. An issue was raised regarding the accuracy of Jacobians computed by AI/ML based models.

Recommendation RTSP-5 to the group
    Support an ISSI proposal to do visible RTM intercomparisons and developments (due January 2022).

Recommendation RTSP-6 to developers
    Ensure that AI/ML Jacobians are properly evaluated and possibly corrected using, for instance, regularization techniques.

The group discussed the development of fast RT models in the UV. It was noted that there are plans in place for CRTM 3.0 and perhaps for RTTOV 13.1 possibly using a LUT based

approach in RTTOV 13.2. An issue was raised regarding the minimum version of LBLRTM/Line Parameter database for UV support. It was agreed that LBLRTM v12.8 should be suitable. The status of fast NLTE models was discussed. Proposed upgrades include the extension of the training to larger solar angles and the inclusion of ozone variability as well as the use of state-of-the-art vibrational temperatures.

Recommendation RTSP-7 to developers
> **The group encourages the development of fast models in the UV.**

Recommendation RTSP-8 to developers
> **Improve the training of NLTE fast models by including larger solar angles, ozone variability and state-of-the-art vibrational temperatures.**

The group discussed the development of fast RT models in the IR and far IR and the use of ML techniques. It was noted that within the framework of CRTM, ML techniques have been applied to computations used for transmittance coefficient generation in clear sky. This resulted in higher accuracy and possibly speed increase. However, there are issues with adjoint computations. An AI version of CRTM (CRTM-AI) has been noted.

RTTOV has been extended to the simulation of far IR radiances (e.g. FORUM). CRTM has plans but there is no explicit testing yet. Upcoming sensors might include PREFIRE. The status of spectroscopy and continuum modeling in the far IR has been discussed. A comparison is planned between 4A and LBLRTM/RTTOV to study the impact of different spectroscopic databases.

Action RTSP-4 to Raymond Armante and Jerome Vidot
> **Communicate to the group results of the 4A-RTTOV comparison.**

2.1.4 RT model validation

The group discussed the validation of RT models putting a special emphasis on validation data sets for cloudy cases. The RT subgroup has a profiles datasets webpage, but these are focused on clear sky radiative transfer calculations. Although there have been cloudy RT model intercomparisons, atmospheric datasets to assess the absolute accuracy/precision of these models are needed. Cloudy RT validation data sets could be coincident with satellite-based radiances but the atmosphere, cloud properties and scene complexity needs to be characterized.

Recommendation RTSP-9 to developers
> **The group recommends the development of cloudy RT model validation datasets**

2.1.5 Reference / on-orbit calibration

The group discussed the Solar Pathfinder follow on from CLARREO, the European mission in UKSA+ESA TRUTHS mission and the FY5-Libra China benchmark mission. The need for traceability from Spectroscopy to RT and validation using SI traceability methodologies was discussed.

Recommendation RTSP-10
> **The group recommends IR support for follow on from CLARREO.**

Action RTSP-5 to Ben Johnson
Find prior traceability recommendation, possibly from other meeting.

2.1.6 Optical and Physical Properties: Aerosols, Clouds, and Precipitation Model Solvers and Approximations

Recommendation RTSP-11 to developers
Physical consistency should be sought where possible. The use of a single comprehensive database and the development of unified solvers for fast RT model should be pursued.

Recommendation RTSP-12 to developers
An accurate valuation of UV/Vis/near-IR errors/issues should be carried out.

2.1.7 Fast model coefficient generation and fast RT model intercomparison
The group discussed the possibility of establishing a reference dataset for AI training possibly using a common approach for RT and DA applications. An intercomparison between CRTM and RTTOV is ongoing through JEDI/UFO (clear sky so far). The planned validation of SARTA/kCarta based on co-located sondes was noted.

Recommendation RTSP-13 to developers
Include new fast models in the intercomparisons, possibly adding scenes that include clouds and aerosols.

Recommendation RTSP-14 to developers
Add validation component (e.g., soundings, field experiment data), GNSSRO

2.1.8 PC based approaches for data assimilation
The availability and the development of PC based fast RT models has been reviewed. The use of PC based fast RT models developed at ECMWF, Met Office and NASA is now well established.

Recommendation RTSP-15 to users
Exploitation of PC based data requires PC based fast models. In particular, reconstructed radiance observations and reconstructed radiance simulations should be based on the same eigenvector basis.

2.1.9 Surface properties
A digitized dataset of refractive indices for sea surfaces was presented. A comparison between CRTM and RTTOV sea surface emissivity models is planned as well as the validation of sea surface emissivity models using AIRS data. The development of the ISSI reference model (primarily in the MW) was noted.

The CAMEL dataset is being updated to version 3 based on MODIS c6.1. The dataset covers the short wave and an extension to the far IR is planned.

The development of a physical model for snow/ice is planned for CRTM. Snowpack modeling at MW frequencies has also been noted. It was observed that models used in broadband radiations schemes should be consistent with models used for data assimilation.

The group discussed BRDF modeling considering the validity of statistical approaches vs. physical modeling. The utility of atlas-based approaches was questioned. The group also discussed the definition of skin temperature noting that this requires precise definitions/assumptions. The need for community defined / agreed standards for "in practice" usage was noted. This requires information exchange.

Recommendation RTSP-16 to community
    Coordinate efforts for LS Emissivity modeling to cover spectral and physical requirements, development of modeling framework.

Recommendation RTSP-17 to community
    New SST / SSE measurements across all spectral ranges highly encouraged, in coordination with RT model developers / researchers with particular emphasis on temperature dependence.

Action RTSP-6 to Ben Johnson
    LSWG coordination of recommendations.

2.1.10 Future developments
- Fast RT models used in NWP operational systems
  - CRTM v3, RTTOV v14 with full polarization support and UV support
  - ARMS model (some feedback is needed here)
  - New / upcoming fast models with TL/AD support?
  - AI approaches
- Fast RT models used for research/retrievals
  - SARTA: update planned based on new HITRAN data
  - ARTS: (need to touch base with ARTS team for updates)
- Spectroscopy
  - Databases: GEISA 2020, HITRAN 2020
- LBL
  - CLBLM?
- Surface
  - Physical -> Radiance modeling improvements, full polarization / BRDF