ITSC-24 Radiative Transfer and Surface Properties Working Group (RTSP)

Co-chairs: Vito Galligani (UBA), Ben Johnson (JCSDA)

- Here's some topics that we cover in detail:
  - Spectroscopic needs:
    - the fundamental properties of spectroscopic absorption / emission lines (among other things)
  - Line-by-line needs:
    - accurate, efficient and highly flexible model for calculating spectral transmittance and radiance
  - FAST RT needs
    - Portions trained on LBL but substantially faster
    - Aerosols, clouds, precipitation, complex surfaces, NLTE, Zeeman, convolution with antenna patterns, etc.
    - e.g., CRTM, RTTOV, ARMS, σ-FORUM, etc.
  - AI methods
    - New tools to accelerate / replace various elements of the above
  - Action items / Recommendations

Participants in ITSC-23 RTSP-WG

Akira Ando	Filomena Romano	Leanne Avila	Sergio Machado
Raymond Armante	Hank Revercomb	Ahreum Lee	Silke May
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Benjamin Johnson*	Indira Rani S	Leonhard Scheck	Patrick Stegmann
Christina Köpken-Watts	Ishida Haruma	Marco Matricardi*	Stephanie Guedj
Christina Stumpf	James Hocking	Ming Chen	Stephen English
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Interim Working Group Meetings [1/2]

Feb 29, 2022

Section 1 (1400 - 1500): Spectroscopy improvements and direct applications

Talk 1 (15min): Iouli Gordon:HITRAN update
Talk 2 (15min): Marco Matricardi: NWP update
Talk 3 (15min): Eli Mlawer: LBLRTM update

Section 2 (1500 - 1600): RT modeling updates: Research models, fast models, AI approaches

Talk 1 (10min): Patrick Stegmann (AI activities)
Talk 2 (5 min): Benjamin Johnson (CRTM update)
Talk 3 (15min): James Hocking: RTTOV activities
Talk 4 (15min): Nick Nalli: emissivity update

Open discussion

- Spectroscopic needs
- Line-by-line needs
- FAST RT needs
- AI methods
- Action items leading into ITSC-24 (spring 2023) [we never got to this part!]

Interim Working Group Meetings [2/2]

Monday 26 September at 1400 UTC (10am ET) (discussion only, no presentations)

New Co-Chair introduction (Vito)

Open discussion:

•Spectroscopic needs
- Continuous support/maintenance of molecular databases
- Speed dependent molecular parameters
- What is the accuracy of molecular parameters in the Visible/UV?
- Molecular parameters for HDO
- Ozone issues?
- Line mixing, especially CO2

•Line-by-line needs
- Continuous Support/Maintenance of currently available LBL models
- Any new LBL model on the horizon?
- Speed dependent Voigt line shape
- Vibrational temperatures for NLTE
- Use of alternative molecular databases?

•FAST RT needs
- Improvement/revision of the fast transmittance model approximation used for the solar term and solar source function
- Improvement of NLTE models

Scattering in the visible for clouds and aerosols

Extension to the far IR and UV regions
- Optical properties of scattering particles and their consistency across the spectrum
- Unified approach for scattering solver across parts of the spectrum?

Full scattering capability

•AI methods

LBL model [1/2]

Summary: 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.

LBL model [2/2]

Summary: 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.

Spectroscopy [1/1]

Summary: 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 exist of 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 CO_2 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.

Fast RT models in the near IR, Visible and UV. NLTE effects in the near IR [1/2]

Summary: 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.

Fast RT models in the near IR, Visible and UV. NLTE effects in the near IR [2/2]

Summary: 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-6 to developers: the group encourages the development of fast models in the UV.

Recommendation RTSP-7 to developers: improve the training of NLTE fast models by including larger solar angles, ozone variability and state-of-the-art vibrational temperatures.

Fast RT models in the IR and far IR, machine learning approaches [1/1]

Summary: 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-5 to Raymond Armante and Jerome Vidot: communicate to the group results of the 4A-RTTOV comparison.

RT model validation [1/1]

Summary: 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-8 to developers: the group recommends the development of cloudy RT model validation datasets

Reference / on-orbit calibration [1/1]

Summary: 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-9 : the group recommends IR support for follow on from CLARREO

Action RTSP-4 to Ben Johnson: find prior traceability recommendation, possibly from other meeting

Optical and Physical Properties: Aerosols, Clouds, and Precipitation Model Solvers and Approximations [1/1]

Recommendation RTSP-10 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-11 to developers : an accurate valuation of UV/Vis/near-IR errors/issues should be carried out.

Fast model coefficient generation and fast RT model intercomparison [1/1]

Summary: 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-12 to developers : include new fast models in the itercomparisons, possibly adding scenes that include clouds and aerosols.

Recommendation RTSP-13 to developers : add validation component (e.g., soundings, field experiment data), GNSSRO

PC based approaches for data assimilation [1/1]

Summary: 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-13 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.

Surface properties [1/2]

Summary: 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.

Surface properties [2/2]

Summary: 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-14 to community: coordinate efforts for LS Emissivity modeling to cover spectral and physical requirements, development of modeling framework.

Recommendation RTSP-15 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-5 to Ben Johnson: LSWG coordination of recommendations

Future developments [1/1]

- 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 for
- LBL
  - CLBLM?
- Surface
  - Physical -> Radiance modeling improvements, full polarization / BRDF