



# **Radiative Transfer and Surface Properties Working Group Report**

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ITSC-22

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Co-Chairs: Marco Matricardi, Benjamin T. Johnson

# Participants in ITSC-22 RTSP-WG

Name	Name	Name
Marco Matricardi*	Kozo OKAMOTO	
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Daniel Zhou	Hidehiko MURATA	
Robert Knuteson	Masahiro Kazumori	
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Michelle Feltz	James Hocking	
Eva Borbas	Steve English	
Eunhee Lee		
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Stefano Migliorini		

Note: more names to be added after folks fill out the google forms link sent via email.

# Topics Covered in ITSC-22 RTSP-WG

Fast RT Model Coefficient Generation

Line-By-Line Models

Spectroscopic Parameters

Surface Properties

Optical and Physical Properties: Aerosols, Clouds, and Precipitation

Model Solvers and Approximations

Validation of RT Model physical assumptions and RT calculations

Fast RT Model Intercomparison

Coordination of Recommendations

Future RT Outlook

# Fast RT Model Coefficient Generation [1/2]

**Summary:** The RTSP-WG seeks to improve the availability and quality of spectral response functions needed to generate accurate coefficients required by fast RT models.

**Recommendation RTSP-1 to Fast Model Developers:** Fast non-LTE models should include a representation of Ozone variability in the mesosphere in support of shortwave radiance simulations.

**Recommendation RTSP-2 to CGMS:** to encourage sensor manufacturers and instrument engineering and science teams to provide SRFs with higher quality, consistent format, and with rapid availability. Commercial providers need to provide SRFs, APCs, and calibration information in support of RT.

# Fast RT Model Coefficient Generation [2/2]

**Recommendation RTSP-3 to GSICS and CGMS/WMO/SATURN:** Maintain and update Spectral Response Function databases for all available sensors, focusing on operational sensors. Recommend calibration information from sensor to be applied to RTM / SRF.

**Action RTSP-1 Benjamin Johnson:** Create Community SRF repository and coordinate inputs from RTWG and other contributors. Continue to support previous recommendations of creating a spectral response function (SRF) repository, to be shared publicly with the RT community.

# Line-By-Line Models [1/2]

**Summary:** RTSP-WG seeks to improve the quality of LBL models (including underlying spectroscopic databases), and support diversity and continued development and funding for LBL modelling efforts.

**Recommendation RTSP-4 to the RT and LBL community:** The RTSP-WG strongly supports continuous line-by-line model development as a fundamental basis for accurate radiative transfer calculations in fast RT models. The RT community also encourages and supports the development of competing line-by-line codes (encourage innovation and diversity). [continued]

**Recommendation RTSP-5 LBL Developers:** Encourage line-by-line model developers to include a better formulation of the Voigt line shape (e.g., include velocity dependence)

**Action RTSP-2 Raymond Armante:** To communicate results obtained using a speed dependent formulation of the Voigt line shape providing an assessment of the impact in the infrared region of the spectrum, especially in the long-wave.

# Line-By-Line Models [2/2]

**Recommendation RTSP-6 Fast RT and LBL community:** Look at the current continuum absorption models at higher MW frequencies ( $< 1000$  GHz) and investigate the use of MTK\_CKD model in line-by-line microwave codes. Including Far-IR in support of new missions.

**Recommendation RTSP-7 LBL developers:** Characterization of LBL model biases and uncertainties, especially focusing on warm and moist air masses. Attempt to map uncertainties in spectroscopy into radiance uncertainties, starting from major lines of a given region.

**Action RTSP-3 Marco Matricardi:** to communicate to the working group on the CO<sub>2</sub> perturbation impact on LBL radiances, and to provide a report on the perturbation of the line mixing model.

# Spectroscopic Parameters

**Summary:** Similar to our support for line-by-line modeling improvements, we also seek to encourage the development and the improvement of spectroscopic databases, particularly with respect to those databases that support LBL models. We address a specific need for extending research into higher microwave frequencies that will be used on future sensors.

**Recommendation RTSP-8 to spectroscopic model developers:** A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. Continuous efforts should be maintained in the generation and improvement of basic line parameters.

**Recommendation RTSP-9 to spectroscopic model developers:** The RTSP-WG recommends promoting research into spectroscopy of higher frequency microwave channels up to 1000 GHz.



# Surface Parameters [1/2]

**Summary:** The following recommendations are aimed at strengthening the research aspects of surface modeling and associated RT simulations, and encourages communication and collaboration between and within the physical modeling and RT modeling communities.

**Recommendation RTSP-10 to the physical modeling community, ICWG, ISWG, IPWG, IWWG:** recommendation to the modeling community to develop accurate physical models to support emissivity modeling requirements in RT models.

**Recommendation RTSP-11 to reference-quality model developers:** The RTSP-WG strongly recommends support of developing reference-quality ocean-surface emissivity modeling, specifically Infrared, Microwave, for both active and passive simulations. Support the development of a reference surface emissivity model (English, et al.)

# Surface Parameters [2/2]

**Recommendation RTSP-12 to Vegetation Modeling Community:** recommendation to spectral library developers to include broader and more diverse vegetation sampling (e.g., new types), and include the effects of senescence. Also include the impact of the diurnal cycle.

**Action RTSP-4 on ISWG:** Identify group that can provide broadened vegetation parameters in support of the spectral databases.

**Recommendation RTSP-13 to Snow Modeling Community:** Determine the classification methodology for emissivity modeling over snow free land surfaces, statistical vs. physical or some mixture thereof? (Ruston to iterate)

**Recommendation RTSP-14 to Surface Modeling community:** Improve the interface between land surface model parameters and RT models, and specifically incorporate angular dependence impact on polarized emissivity and reflectivity over all surface types. Include, specifically, the temperature dependence of the index of refraction.

**Action RTSP-5 Nick Nalli, Stu Newman, Steve English:** Identify Up-to-date laboratory measurements across spectral ranges [UV-MW] and resolution of interest for various surface properties (land, water/ocean, snow cover, sea-ice), and anything that's missing, specifically include Far-IR.

# Optical and Physical Properties: Aerosols, Clouds, and Precipitation[1/2]

**Summary:** The optical properties of aerosol, clouds, and precipitation particles require continued support to improve physical and radiometric accuracy. The accuracy of scattering computations can be significantly affected by errors and uncertainties of the parameterization of optical properties of the scattering particles.

**Recommendation RTSP-15 to aerosol/materials modeling laboratories:** The RTSP working group recommends encouraging research into laboratory measurements of aerosol refractive indices [need input on which aerosols need attention]

**Recommendation RTSP-16 Fast RT model developers:** explore the necessity of using non-spherical aerosol particle scattering properties in fast RT models in support of detailed scattering calculations (e.g., LIDAR).

**Recommendation RTSP-17 to RT and physical model developers:** extend the comparison of parameterized schemes, including both clouds and aerosols to explore the validity of current schemes.

# Optical and Physical Properties: Aerosols, Clouds, and Precipitation[2/2]

**Action RTSP-6 on Benjamin Johnson:** to continue report on current developments of physical and scattering properties of aerosols, clouds, and precipitation to the RTSP working group. These links will be hosted on the RTSP WG webpage. [continued action]

**Recommendation RTSP-18 ice/precipitation model developers:** For all scattering/absorbing particles, extend the frequency range to cover the ranges of current and upcoming sensors, from visible to microwave (i.e., ICI channels). Extend the range of particulate sizes to be consistent with observed parameters for each particle type.

**Recommendation RTSP-19 laboratory property modelers:** Far-IR studies of temperature dependent index of refraction.

# Model Solvers and Approximations

**Summary:** Scattering approximations used in fast RT models are essential for operational use within simulations involving scattering atmospheres. The RT community should compare results from scattering model solvers to both each other, and to external models.

**Recommendation RTSP-20 to RT developers:** encourage the comparison / validation of full scattering solvers. This should include the computational efficiency, specifically including the adjoint model.

**Recommendation RTSP-21 to RT developers:** for aerosol scattering computations, more research is needed to characterize the regimes where fast RT approximations are effective.

**Recommendation RTSP-22 to RT developers:** to look at the importance of simulating radiances in turbulent layers in coordination with model developers.

# Validation of RT Model physical assumptions and RT calculations

**Summary:** In the pursuit of traceability, improved accuracy, knowledge of uncertainties, and in support of development of reference models, careful validation datasets must be made available to the community for use in RT calculation assessments.

**Action RTSP-7 on Benjamin Johnson, Marco Matricardi:** to maintain and update list of "golden" field experiments (variety of observations, high data quality, good sensor overlap/coverage), need input from instrument scientists and other key users/developers. [Previous actions on providing validation datasets are merged into one action.]

**Action RTSP-8 on Marco Matricardi:** to provide link on MAGIC campaign calibrated datasets.

# Fast RT Model Intercomparison

**Summary:** Continue CRTM/RTTOV/ARMS model intercomparisons and expand it slightly to cover both clear-sky and cloudy RT comparisons.

**Action RTSP-9 James Hocking, Benjamin Johnson** to coordinate intercomparison effort. JEDI/UFO is a possible framework. Aim toward developing a standardized intercomparison framework for testing new coefficient files / scattering tables, etc. Will also reach out to ARMs developers to include them in the effort.

# Coordination of Recommendations

**Summary:** Fostering communication between various working groups is essential to reduce the duplication of effort and to promote collaborative cross-group activities.

**Action RTSP-10 to the RTSP-WG Co-Chairs and members:** share RTSP recommendations with other relevant working groups (e.g., ITSC, IPWG, ICWG, IWWG, ISWG, ISDA, and other groups where reference radiative transfer will be of interest). Individuals from RTSP-WG should volunteer to present recommendations at their respective meetings.

**Recommendation RTSP-23 to the RT model development community:** promote the extension of RT models to the simulation of active/passive data (e.g., Radar/LIDAR/Scatterometers), and to UV, Visible, and Far-Infrared portions of the spectrum. A accurate treatment of atmospheric, spectroscopic, and surface polarization (linear and circular) should also be considered in support of these bands.



# Future RT Outlook

**Summary:** Fast RT models should be responsive to upcoming requirements arising from NWP or other communities. We specifically identify areas importance that need to have some early attention and discussion. It is expected that these items will move up into other areas as requirements and research progresses.

**Recommendation RTSP-24 to the RT modeling community and partners:** Support the development of a set of community models for building a reference standard radiative transfer model, but using existing reference models where available (e.g., LBL, Spectroscopic databases).

**Action RTSP-11 on the IRRTM team:** Deliver whitepaper and present on the International Reference Radiative Transfer Model (IRRTM) status and planning to ITSC, IPWG, ICWG, IWWG, ISWG, ISDA, and other groups where reference radiative transfer will be of interest.

HLPP ITEMS OF RELEVANCE TO RTSP-WG	Working Groups	Support for LBL models: Additional support needs; Consensus on which LBL Models require support	RT
New sensors and data: FY-4A GIIRS; FY-3D HIRAS+MWTS+MWHS; Metop-C IASI; NOAA-20 ATMS and CrIS; Data evaluation, assimilation, and NWP impact; Plans for demonstrating value of upcoming FY-3E early morning satellite	International, NWP, RT, Advanced, Products	Radiative transfer developments: Specific needs for better spectroscopy; uncertainty in spectroscopy and effect on BT modelling; intercomparisons of forward calculations vs high quality sondes and radio-occultation; specific needs for cloudy/aerosol-affected RT	RT, NWP
Future sensors and data: Metop-SG IASI-NG and MWS; MTG IRS; Preparation for Data distribution; Data Assimilation (e.g., reconstructed radiances vs. PC scores); DB processing software for new sensors	International, NWP, RT, Advanced, Products	Use of sounding data in cloudy regions, MW + IR: Current issues; Best practises; What areas need advancements, Assimilation/retrieval strategies	RT, NWP, Products
Preparations for future missions: Best-practices for user-interaction, e.g., data simulation, dissemination testing, ensuring overlaps between satellites, etc	International, NWP, RT, Products	Observation errors: Higher sophistication (situation-dependent variances, correlations – inter-channel & spatial); what DA developments needed	NWP, RT
Efficient use of hyperspectral IR data: assimilation of PCs and reconstructed radiances, PCs and CDRs, PC RT models, Level 2 products	RT, NWP, Climate, Products	Data Biases: treatment, attribution, constraints	NWP, RT, Products, Climate
Apodisation: Consensus on which apodisation for future instruments; Case for dissemination of self-apodised spectra; Need for fast RT development for unapodised spectra	Advanced, RT	Validation: sharing and joint analysis of results during cal/val phase, validation datasets/reference observations, field campaigns, NWP monitoring and assimilation	RT, NWP, Products, Climate
Use of surface information: Emissivity estimates and models; Reference ocean emissivity model, Realistic representation of the land surface, cloud screening over land	RT, NWP, Products	Instrument characterisation: Acquisition and validation of SRFs, band-passes, polarizations, antenna temperature corrections, SI traceability	RT, NWP