Assessment of Accuracy of Scaling Methods for the Computation of Satellite Spectral Radiances at Longwaves.

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Introduction

Top of the atmosphere synthetic spectral radiances are computed for widespread atmospheric conditions by alternatively using the discrete ordinate algorithm solution or approximate methodologies where the scattering effects are simulated by appropriate scaling of the absorption properties of the diffusive layers [1]. The residuals between the full scattering solution and the scaling methods are evaluated at far- and mid- infrared wavelengths and compared with the goal noise of the **FORUM** (Far-infrared Outgoing Radiation Understanding and Monitoring) satellite sensor, that will be the next European Space Agency (ESA) 9 th Earth Explorer, capable of spectrally resolved measurements in the 100–1600 cm −1 band.

Approximate Methodologies

Chou Approximation (CA)

The scattering contribution is accounted for by replacing the optical depth (τ) with an apparent optical depth for extinction:

$$\tilde{\tau} = (1-\omega_0)\tau + b\omega_0\tau$$

Similarity Principle

The full scattering computation is avoided by considering an apparent optical depth for extinction:

$$\tilde{\tau} = (1-\omega_0)\tau + \frac{(1-g)}{2}\omega_0\tau$$

Accurate computation and Parameterization of b

$$b = \frac{1}{2\pi}\int_0^{2\pi} d\Phi \int_0^{2\pi} d\Phi' \int_0^1 d\mu \int_{-1}^0 d\mu' \frac{P(\mu,\Phi,\mu',\Phi')}{4\pi}$$

Monte Carlo

$$b \cong \frac{1}{2N}\sum_{i=1}^{N} P(\mu_i,\Phi_i,\mu'_i,\Phi'_i)$$

Chou et al. provides a polynomial fitting of **b** through the asymmetry parameter **g** valid in any cloud conditions:

$$b \cong \sum_{i=1}^{4} a_i g^{i-1}$$

Accurate computations of b (and their parametrizations) are provided for liquid water clouds and for ice clouds composed of aggregated hexagonal columns.
These are obtained from up to date cloud optical property databases.

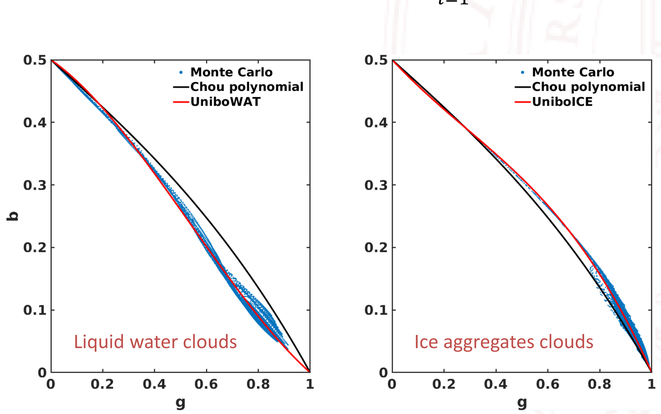

Figure 1. Comparison of the backscattering function b versus the asymmetry parameter g for three computation approaches: exact integral using Monte Carlo (blue dots), polynomial by Chou et al. (black lines), and polynomial fit with updated coefficients (red lines).

Name	Application	a_1	a_2	a_3	a_4
Chou	Liquid water and ice clouds	0.5	0.3738	0.0076	0.1186
UniboWAT	Liquid water clouds	0.5	0.2884	0.5545	−0.3429
UniboICE	Ice aggregates clouds	0.5	0.4452	−0.3189	0.3737

Table 1. Coefficients for the polynomial fitting of b versus g.

[1]: M. Martinazzo et al, "*Assessment of the accuracy of scaling methods for radiance simulations at far and mid infrared wavelengths*" (2021), DOI: https://doi.org/10.1016/j.jqsrt.2021.107739
[2]: U. Amato et al, "*The σ-iasi code for the calculation of infrared atmospheric radiance and its derivatives*", (2002), DOI: 10.1016/S1364-8152(02)00027-0

Radiance Computation and Results

LBLDIS code chain (figure 2.) is used to quantify the impact of scaling methods in the computation of the spectral radiances, with focus on the FORUM spectral region (FIR-MIR).

Figures 3 and 4 show, in the top panel, the TOA spectral radiances computed with the full scattering approach for a 50°N atmosphere in presence of a liquid water cloud layer (figure 3), whose top is placed at 1.5 km and with OD=15, and an ice cloud layer (figure 4), whose top is placed at 8 km height and with OD=1.
The bottom panels show the radiance differences between CA and full scattering approaches for the same clouds.
FORUM instrument noise goal is highlighted by a grey shaded area.

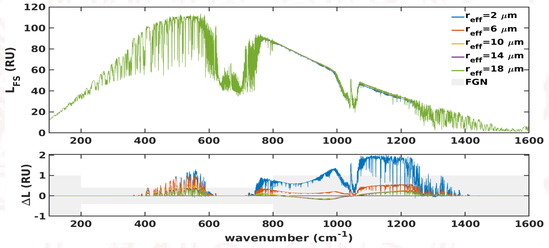

Figure 3

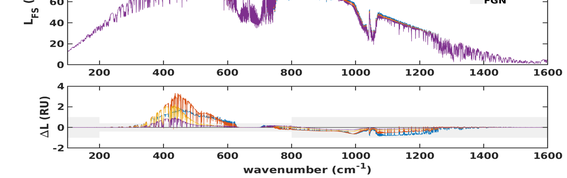

Figure 4

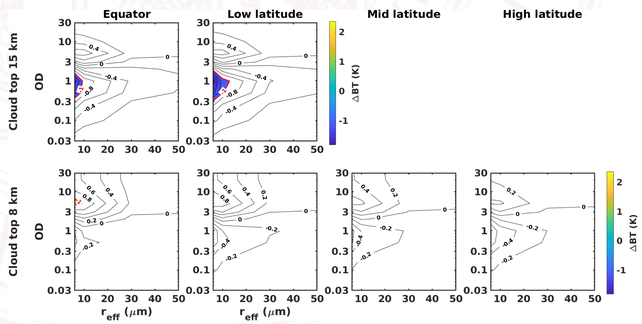

Figure 5. Radiance (ΔL, contour) and brightness temperature (ΔBT, color) differences between CA and full scattering approaches at 1203 cm^{-1}(MIR), for ice clouds.

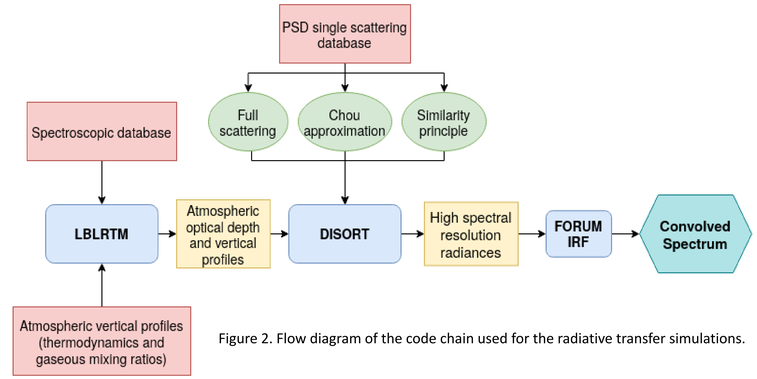

Figure 2. Flow diagram of the code chain used for the radiative transfer simulations.

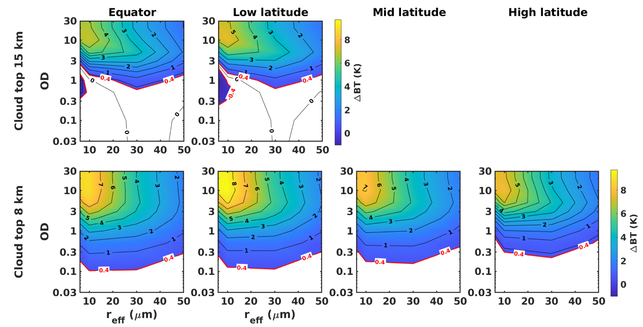

Figure 6. Radiance (ΔL, contour) and brightness temperature (ΔBT, color) differences between CA and full scattering approaches at 410 cm^{-1} (FIR), for ice clouds. The white regions indicates differences below the FORUM noise level.

Conclusions

- In case of both water and ice cloud scenarios, the approximate solutions perform well in the mid infrared for most of the cases studied.
- In the far infrared region, not negligible inaccuracies are observed when approximate solutions are adopted for computations of TOA radiances in cloudy sky.
- The accurate computation of the b parameter from the updated databases is implemented in σ-FORUM [2] fast radiative transfer code.