On the accuracy of RTTOV-SCATT for radiative transfer in all-sky microwave and sub-millimeter frequencies

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Motivations

- At the heart of data assimilation and, passive microwave (MW) and sub-millimetre remote sensing techniques lies a computationally efficient/fast radiative transfer model (RTM)
- As the operational demand of RTMs under scattering media increases, it is key to evaluate their accuracy

	physical models (e.g., ARTS)	operational models (e.g., RTTOV)
Performance	- very accurate, but computationally demanding	- fast, but subject to weaknesses
gas absorption	- line-by-line calculations	- pre-calculated absorption coefficients (and predictors)
Scattering methods	- consider angular dependence of scattered radiation (e.g., discrete ordinate, Stamnes et al.,1988)	- simplified account: discrete angles, no phase function (e.g., two-stream Eddington method, Bauer et al., 2006)

- In preparation for the Ice Cloud Imager (ICI), it is crucial to extend the evaluation of operational RTMs at sub-mm frequencies.

Aims

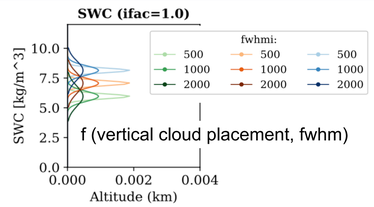
- Intercompare RTTOV-SCATT v13.0 (Saunders et al., 2020) and the reference quality model Atmospheric Radiative Transfer Simulator (ARTS, Eriksson et al., 2011) covering not only the MW frequencies of ATMS, AMSU-A and MHS between 10.65 and 190.31 GHz, but also the submillimetre frequencies of ICI (183.31 and 668 GHz) consistently.
- To scrutinize the performance of the δ-Eddington approximation implemented in RTTOV-SCATT
- To quantify the degree of agreement between the models in all-sky conditions with a special emphasis on the sub-mm
- To establish benchmark results for world–wide model assembly

Identifying potential shortcomings in RTTOV-SCATT v13.0 could potentially improve the forecasts

Methodology

1) Using simple and realistic conditions: FASCOD tropical profiles + simple "gaussian" cloud profiles (ice-only, snow-only, rain-only, and all-sky scenarios) to analyse

a. Differences in gas absorption (spectroscopy / focus on clear-sky)
b. Differences in bulk cloud optical properties
c. Limitations of the δ-Eddington approximation (RTTOV) compared to a more sophisticated method (DISORT, employed in ARTS)



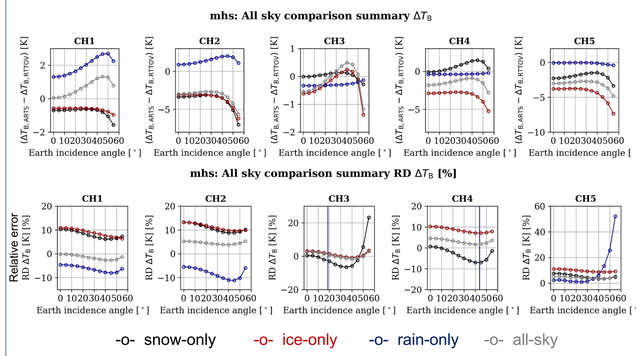
2) "idealized" simulations to identify limitations of the the δ-Eddington approximation in RTTOV

3) Extend analysis to globally representative profiles: ECMWF Integrated Forecast System (IFS) at global AIRS locations

All-sky simple scenarios

(w/ consistent bulk properties)

FASCOD tropical + "gaussian" cloud

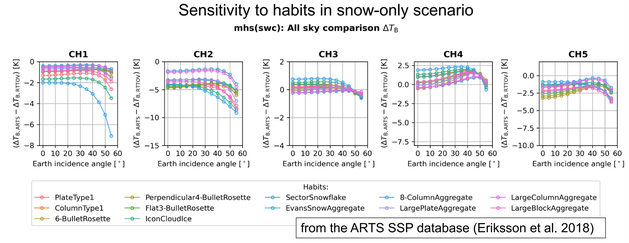


-o- snow-only -o- ice-only -o- rain-only -o- all-sky

Rain: ARTS Liquid spheres + Marshall and Palmer (1948)
Snow/graupel/ice: Large Plate Aggregate (LPA) + tropical Field et al. (2007)

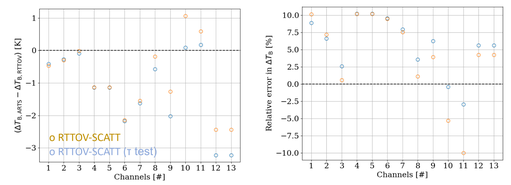
-> compensation for the rain sensitive channels in MHS frequencies

Sensitivity to habits in snow-only scenario



from the ARTS SSP database (Eriksson et al. 2018)

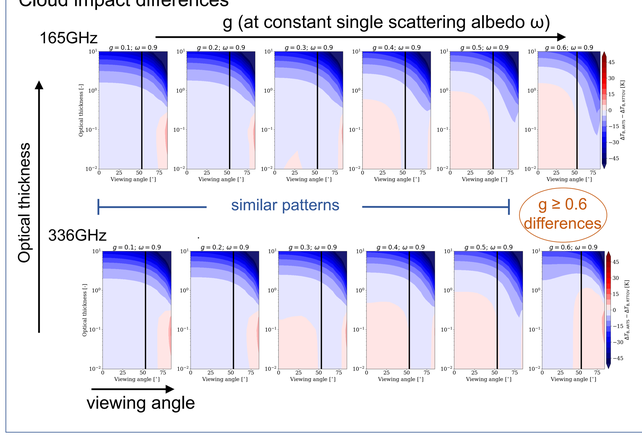
ICI (LPA + tropical Field et al. (2007) ice-only comparison



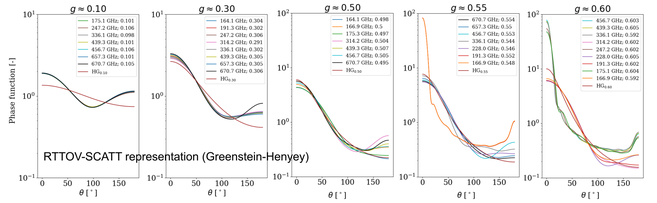
Idealized simulations

scattering-only atmosphere to analyse the behaviour of δ-Eddington

Cloud impact differences



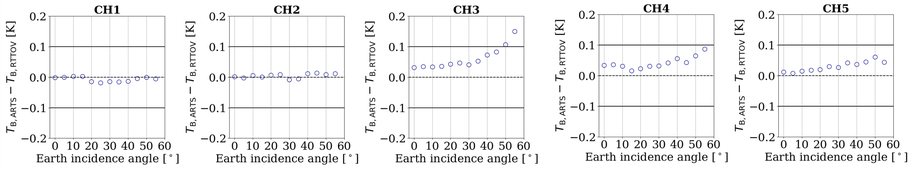
due to differences in phase function (and g)



RTTOV-SCATT limitations:
- Different phase functions can have the same g
- Even a small deviation in **P**, can lead to "large" Tb difference
- for g = 0.1 – 0.5, the phase functions do not deviate much

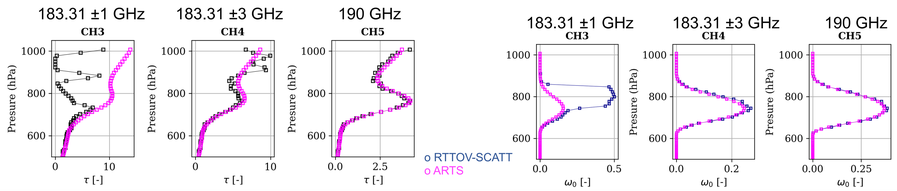
Clear-sky

- excellent agreement (TB and transmission) for all sensors: e.g., **MHS** below



- ICI (not shown) within ±0.1 K for all CHs but for CHs No. 4-5 (243.2 GHz) 0.2 K and No. 9-11 (448 ± 7.2, 3, 1.4 GHz) up to 0.4 K. ICI spectroscopy is under research.
- Discrepancies in optical depth (τ) for both MHS and ICI. Low impact for clear-sky, but τ is supplied to RTTOV-SCATT -> differences in the bulk τ and bulk single scattering albedo (ω_0)

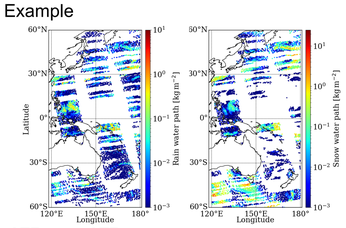
e.g., MHS rain-only simulations at nadir (similar for ICI channels)



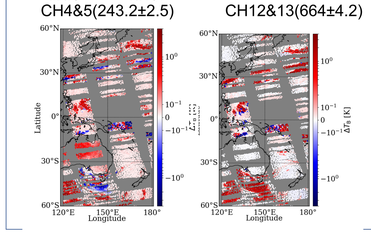
Realistic IFS simulations

ICI simulations

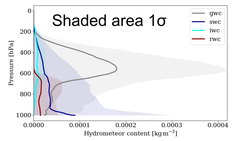
Example



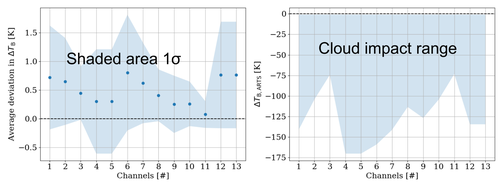
$\Delta TB_{ARTS} - \Delta TB_{RTTOV}$



Statistics over 9000 profiles, covering:
- lats = ± 60°
- lons=>120° & lons < -120°
- viewing angles: 0° - 80°
- RTTOV v13.0 default microphysics



At ICI 53° min/max differences are ±4.5 K (cloudy/precipitating)
If instead look at θ = 0-80° min/max differences -22/7 K



RTTOV v13 default microphysics (SSP / PSD)
Rain: Mie sphere / Marshall and Palmer (1948)
Snow: Large Plate Aggregate / tropical Field et al. (2007)
Graupel: Column Type 1 / tropical Field et al. (2007)
Ice: Large Column Aggregate / modified Gamma (Geer et al. 2021)

RTTOV v13.0 includes the ARTS SSP database

Summary / Outlook

Summary

- Novel effort to scrutinize the limitations of RTTOV-SCATT under scattering media in the MW and also the sub-mm range

Outlook

- Extend realistic IFS simulations to also cover frequencies in ATMS, and GPM (i.e., MW, mm and sub-mm frequencies). Extend ICI simulations to cover > 59k profiles.
- Provide benchmarks from statistics (paper to be submitted).
- Some interpolation issues found in RTTOV-SCATT: needs nadir τ which is calculated for off-nadir angles by τθ*cos(θ)

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