RTTOV development status

ITSC-24, Tromsø, Norway

16 March 2023

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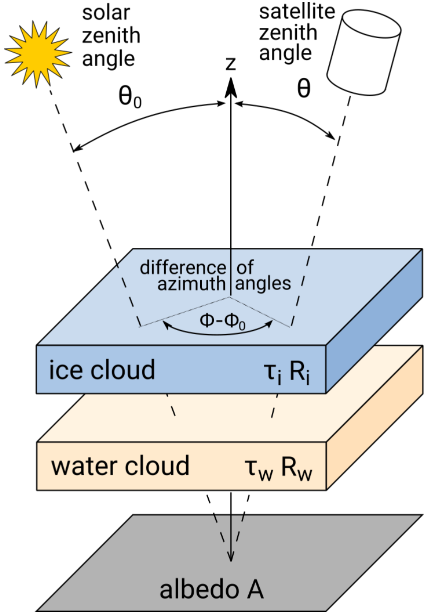
Contents

RTTOV timeline

- November 2020 - **RTTOV v13.0** released
- *June 2021 - ITSC-23*
- November 2021 - **RTTOV v13.1** released
- December 2022 - **RTTOV v13.2** released
- *March 2023 - ITSC-24*
- March 2024 - **RTTOV v14.0** release planned

MFASIS – a fast method for cloud-affected solar channels

Leonhard Scheck, Christina Stumpf, Florian Baur, Christina Köpken-Watts, Olaf Stiller

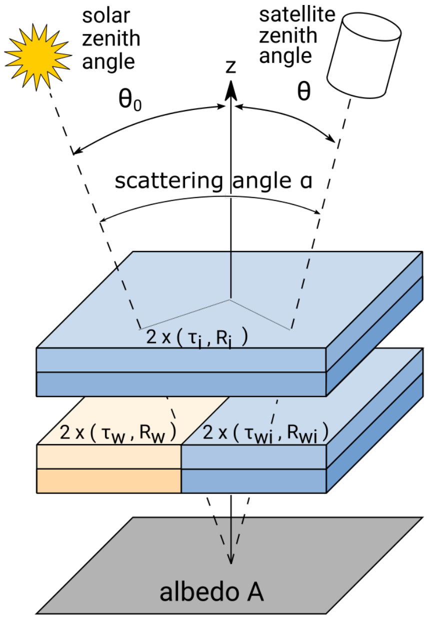


Since RTTOV v12: Look-up table (LUT) based method MFASIS

- Developed for visible channels, with some corrections also usable for 0.8µm & 1.6µm
- Radiative transfer problem is described by 8 parameters (optical depths and effective radii for water and ice cloud, three angles, albedo)
- Reflectances are precomputed with DOM and stored in 8-dimensional LUT, which is compressed from 8GB to 21MB. Interpolation in LUT is fast.
- Additional parameters would lead to large increase in LUT size

See also Leonhard Scheck's presentation 11.06 on Monday

RTTOV v13.2: New input parameters for NIR, LUT replaced by neural network



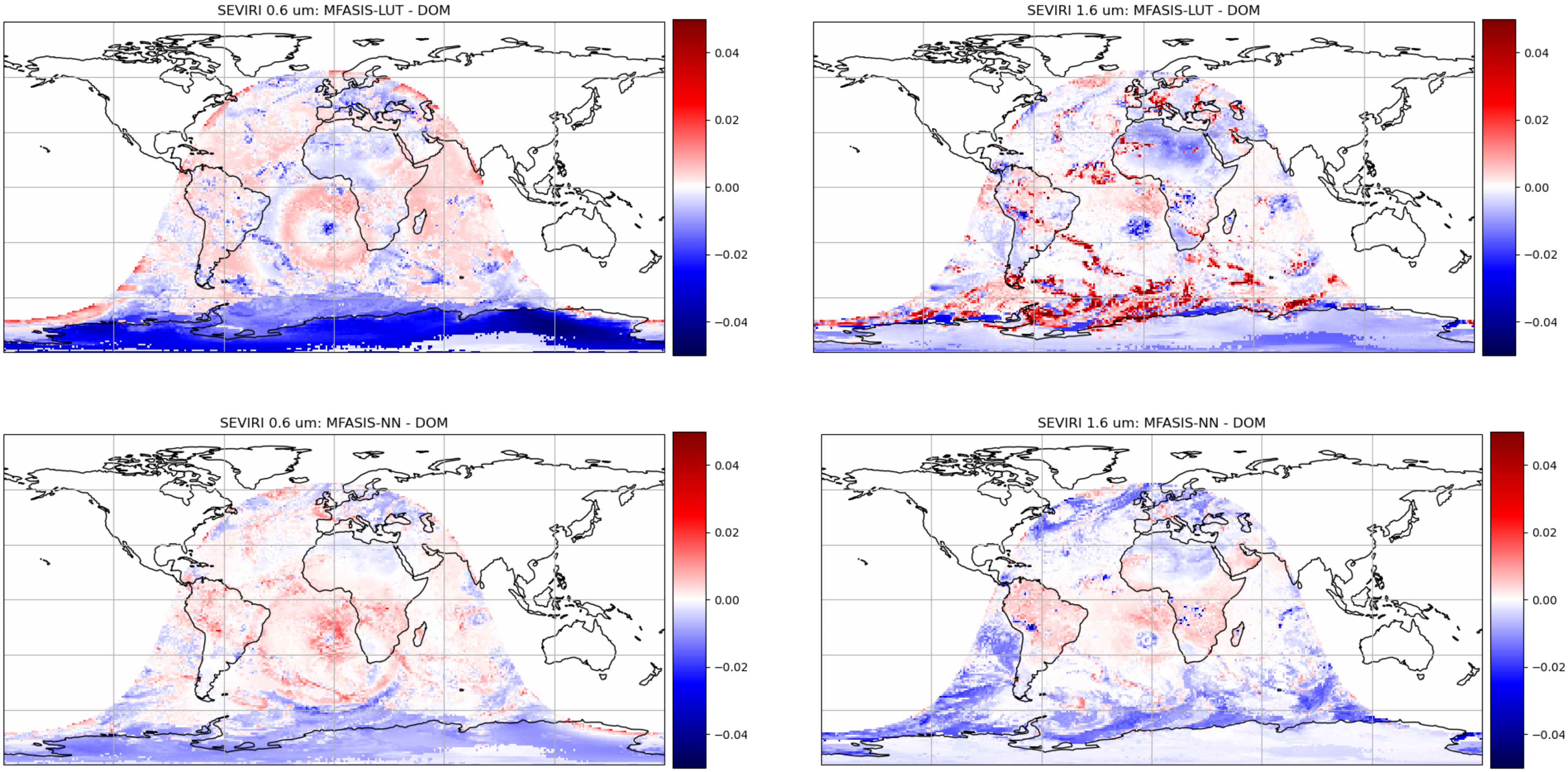
15 parameters for better description of the RT problem, now including also

- cloud top pressure, surface pressure
- mixed phase ice content
- effective radii for upper and lower part of each cloud

→ Improvements for many channels

LUT is replaced by much more efficient feed-forward neural network with 15 input nodes, 6 layers and several 1000 parameters. Training of network requires factor 100 less data to be computed with DOM than for the LUT version.

Performance: In RTTOV v13.2 similar to or faster than LUT version (depends on channel), will be significantly faster when vectorization is finished (in progress)


SEVIRI 0.6 um: MFASIS-LUT - DOM
SEVIRI 1.6 um: MFASIS-LUT - DOM
SEVIRI 0.6 um: MFASIS-NN - DOM
SEVIRI 1.6 um: MFASIS-NN - DOM
0.04
0.02
0.00
−0.02
−0.04

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RTTOV-SCATT – ARO pol scaling

Vasileios Barlakas and Alan Geer

ARO = Azimuthally Randomly Oriented frozen particles.

Improves on empirical scaling and applies to both imagers and sounders.

Based on simulated ARO particles.

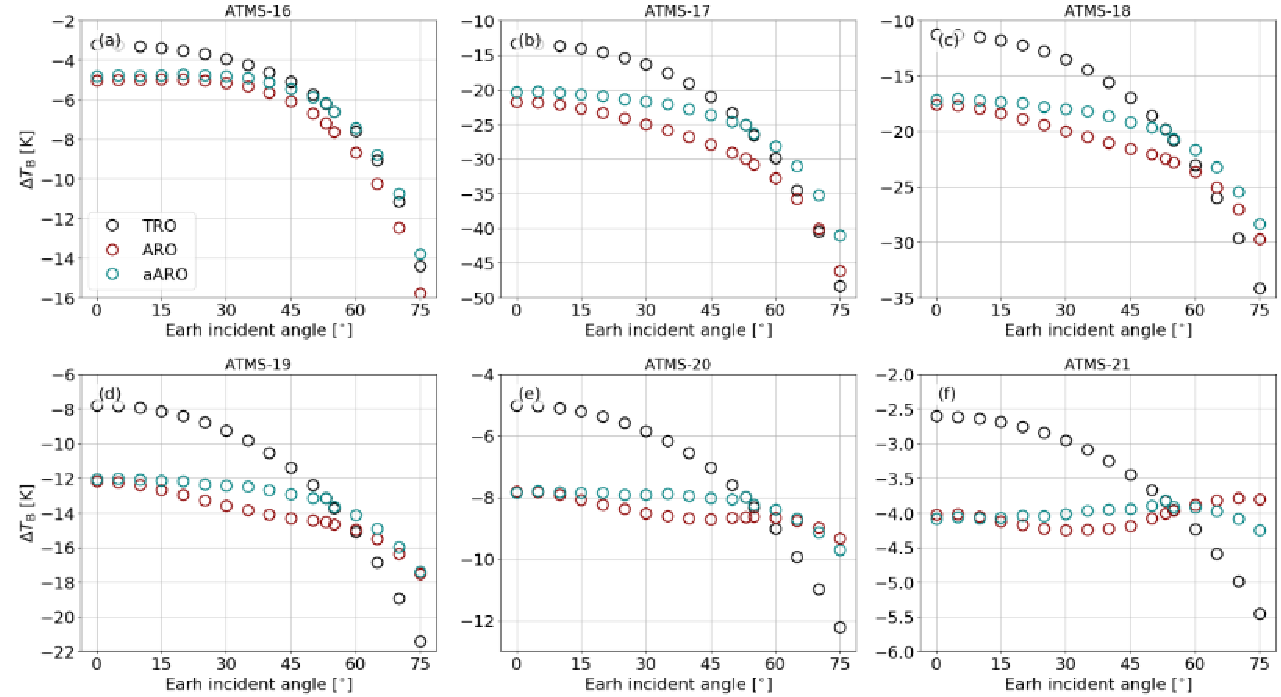
Uses a look-up table in *frequency, zenith angle, temperature* and *water content*.

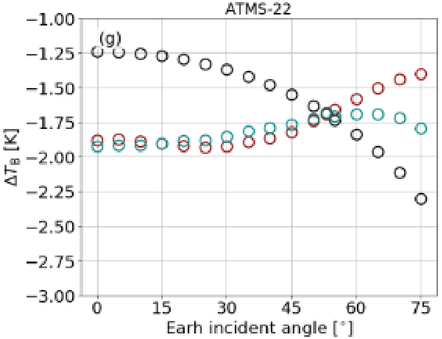
=> requires an additional sensor-independent input file

Scaling factors for all optical properties (*extinction, SSA, asymmetry, reflectivity*) are interpolated from the table.

Validated against fully polarised simulations using ARTS.

Further validation via monitoring planned.





Plots show delta *TB_cloudy* minus *TB_clear* (hydrometeor impact) vs *zenith angle*.

TRO (black) = totally randomly oriented (unpolarised RTTOV-SCATT)
ARO (red) = ARTS fully polarised ARO
aARO (green) = approximate ARO (new RTTOV-SCATT)

https://nwp-saf.eumetsat.int/publications/vs_reports/nwpsaf-ec-vs-061.pdf

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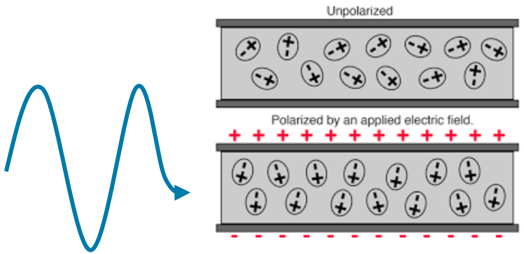
PARMIO - *see Stu Newman's poster 10p.08*

Dielectric model

Emissivity of a flat ocean surface ($\varepsilon_{neutral}$)



Wave spectrum model

PARMIO is a double scale model
- Bragg scattering/geometric optics

Foam model

- Foam coverage
- Foam emissivity

$$\varepsilon = \varepsilon_{Neutral} + \varepsilon_{rough}(OWS) + \varepsilon_{azimuth}(OWS, \varphi)$$

Thanks to Emma Turner

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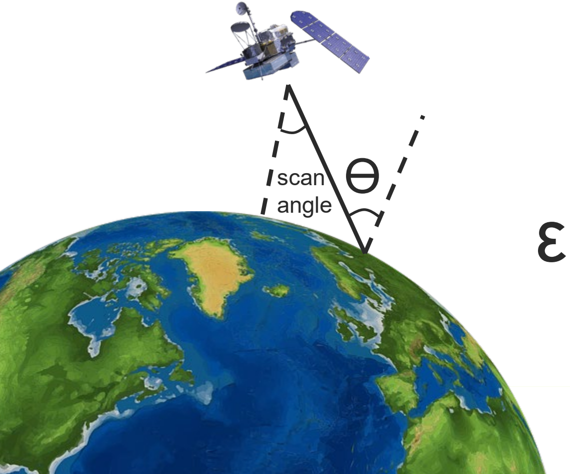
SURFEM-Ocean

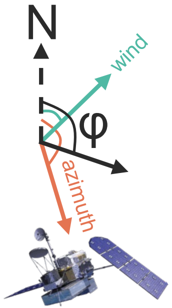
- New fast microwave emissivity model
- Created by Lise Kilic, Carlos Jiminez & Catherine Prigent at the Paris Observatory
- Based on the science in the PARMIO model
- Trained using neural networks

https://nwp-saf.eumetsat.int/publications/vs_reports/nwpsaf-ec-vs-060.pdf



$$\varepsilon = (\nu,\ \theta,\ SST,\ SSS,\ OWS,\ \varphi)$$

- ν: Frequency
- θ: Incidence Angle
- SST: Sea Surface Temperature
- SSS: Sea Surface Salinity
- OWS: Ocean Wind Speed
- φ: Relative wind direction



Thanks to Emma Turner

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Other updates include:

- Extension to UV
- Include depolarisation in Rayleigh scattering phase function.
- ICON-ART aerosol properties
- Updates to MW hydrotable generation
- Option for per-channel effective skin temperature input
- Enable polarimetric (Stokes 3/4) emissivity calculation in FASTEM-6.
- PC score and eigenvector outputs from UWIRemis and CAMEL atlases.
- New user-level helper subroutines:
  - *rttov_calc_solar_angles / rttov_calc_geo_sat_angles*
  - *rttov_get_sea_emis / rttov_get_sea_brdf*

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RTTOV v14 overview *(more details at the RTTOV tech sub-group on Saturday)*

- *Significant* update to RTTOV
- Unifies RTTOV with RTTOV-SCATT:

  => one model for scattering at all wavelengths

  => science in RTTOV-SCATT has been implemented in RTTOV
- Changes to input profile representation.
- Changes to the RTTOV user interface for greater consistency and clarity.
- Some new science implemented… and some features removed.
- **Paid and voluntary beta testers required: 8 weeks in Sept-Oct 2023.**

=> please ask me!

Request from EUMETSAT

EUMETSAT would like to understand which member states are using NWP SAF software packages operationally.

- *RTTOV, Radiance Simulator, 1DVar, CADS*
- *AAPP, MWIPP, IRSPP*

If you are such a user or know of such use please let me know during the conference – thanks :-)

Summary

- Latest version is RTTOV v13.2 released December 2022.
- MFASIS-NN fast solar cloud solver.
- RTTOV-SCATT fast approximate treatment of polarisation.
- New SURFEM-Ocean MW sea surface emissivity model.
- Numerous other updates…
- RTTOV v14 under development => *more details at the RTTOV tech sub-group*
- Available from the NWP SAF website:

https://nwp-saf.eumetsat.int/site/

Thanks for your attention!

Additional slides

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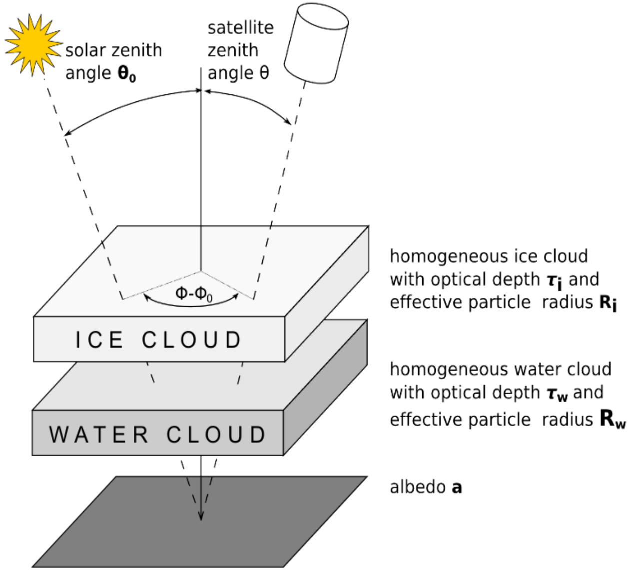
MFASIS fast VIS/NIR cloud parameterisation

Leonhard Scheck, Christina Stumpf, Florian Baur, Christina Köpken-Watts, Olaf Stiller

LUT-based approach, supports selected channels up to 1.6 microns (as of v13.1).

Water vapour handled by interpolating between 3 LUTs.

Mixed phase clouds associated with larger errors: addressed via an empirical correction.



Cannot add new parameters: LUTs are already large.

⇒ difficult to extend to aerosols

⇒ requires empirical/ad-hoc approaches

MFASIS fast VIS/NIR cloud parameterisation

New neural network version implemented in RTTOV v13.2.

Similar accuracy to LUT version and slightly faster (but scope for optimisation).

Initial implementation doesn't support channels affected by water vapour (e.g. SEVIRI 0.8 µm).

Neural network coefficients are a few hundred kB vs ~20MB per LUT (compressed HDF5).

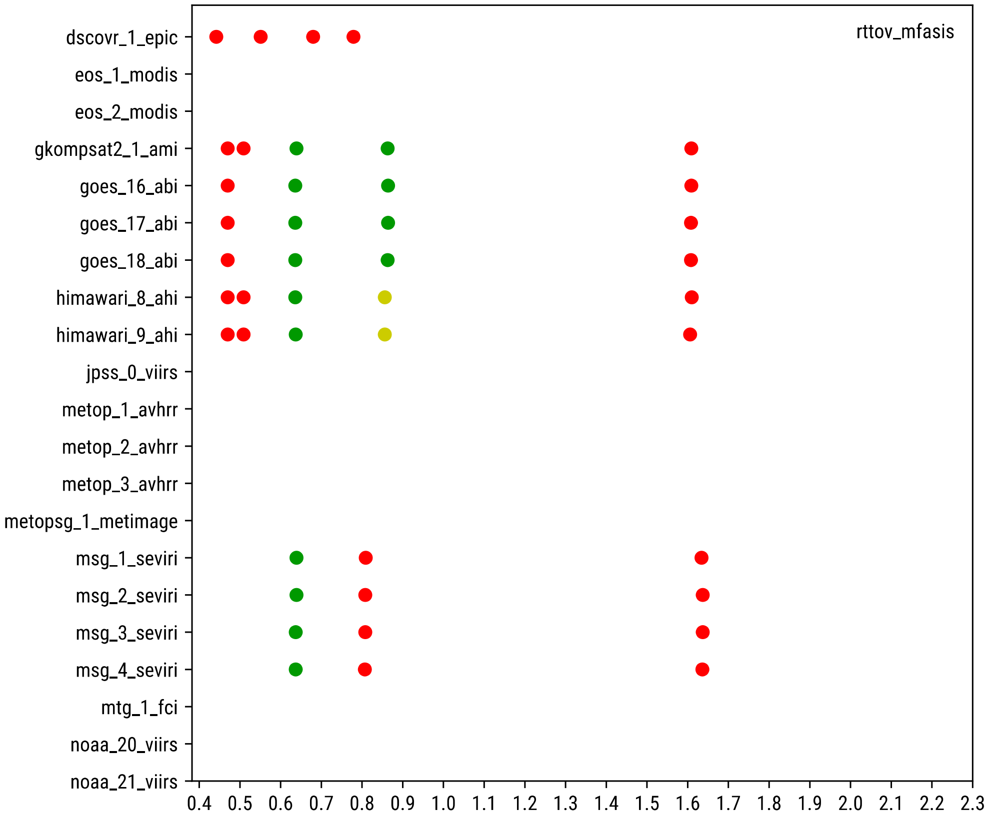
⇒ files distributed in ASCII format (rather than HDF5)

⇒ makes support for hyperspectral UV/VIS sensors a possibility

Neural networks allow arbitrary input parameters – future work

⇒ can be extended to aerosols

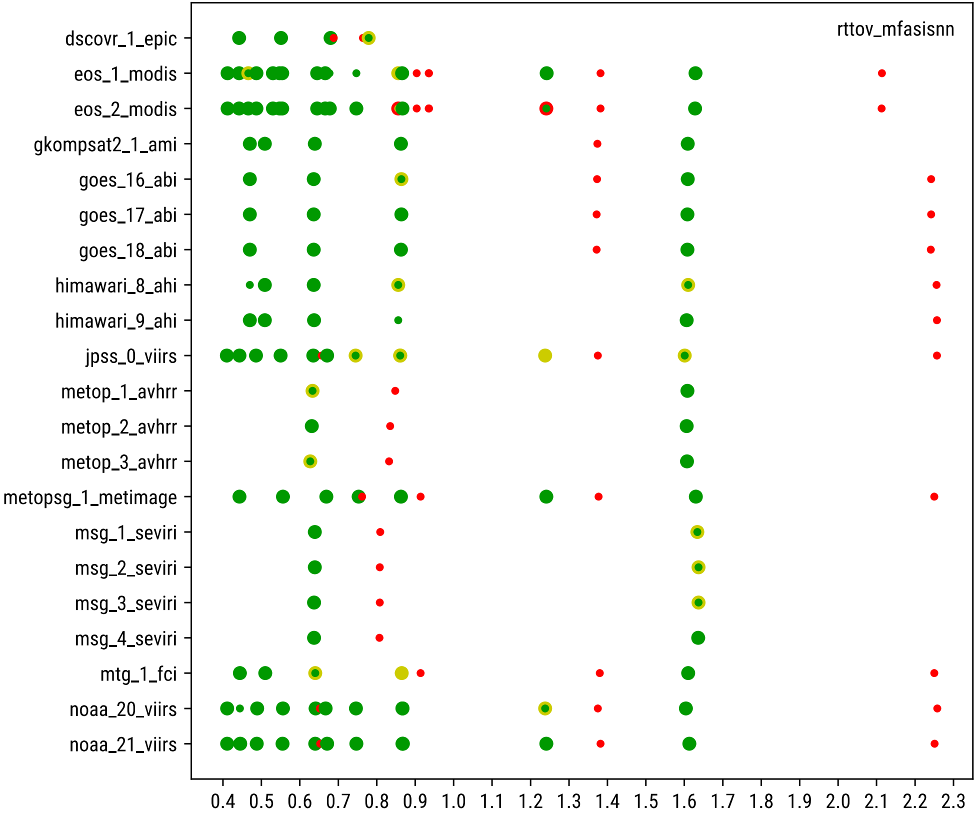
⇒ empirical/ad-hoc corrections can be replaced by directly inputting additional parameters



Available look-up tables for MFASIS

Colors: Reflectance errors are

- **similar to 0.6µm channel**
  (RMSE<0.01 and 99th percentile <0.03)
- **slightly higher**
  (RMSE<0.03 and 99th percentile <0.05)
- **significantly higher**
  (RMSE>0.03 or 99th percentile >0.05)



Available neural networks (MFASIS-NN)

Small red dots: NN not available, errors still too high.

- **Almost all channels with λ<=0.6µm and λ≈1.6µm are now usable**
- 2.2µm channels will work in RTTOV 14 (once water vapor input variable is implemented)
- **0.8µm channels on most instruments work** already, but the broad (more WV sensitive) 0.8µm channels of MSG and MetOp require a second WV variable (work in progress)
- The very WV sensitive 0.9µm and 1.3µm channels require further input variables (under investigation @ LMU/DWD)

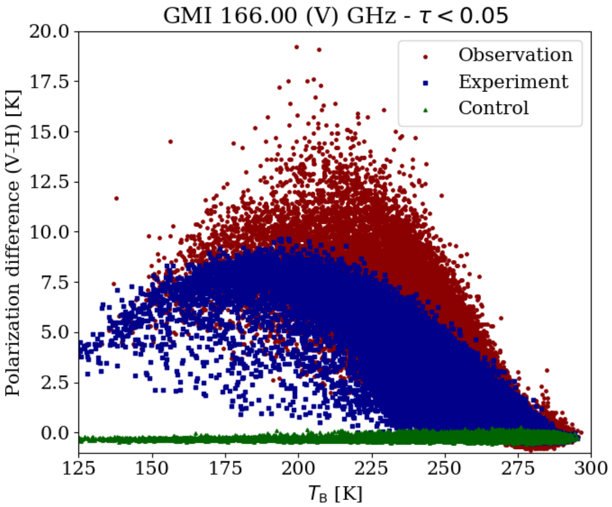
RTTOV-SCATT - polarisation

Vasileios Barlakas and Alan Geer

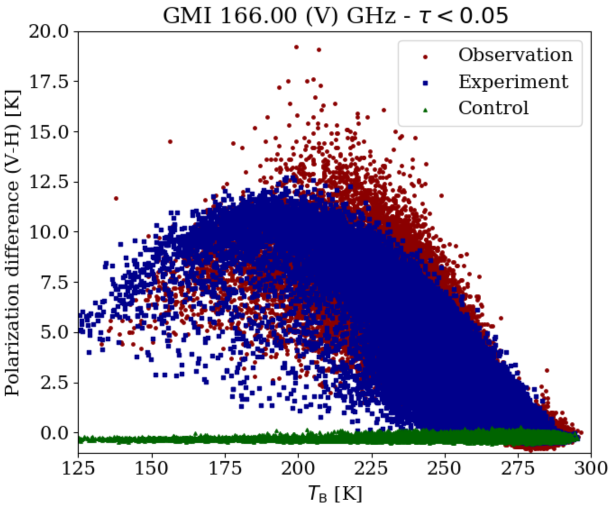
Conical scanners only

AR = extinction h / extinction v = extinction v/h * (1+x) / extinction v/h * (1-x)

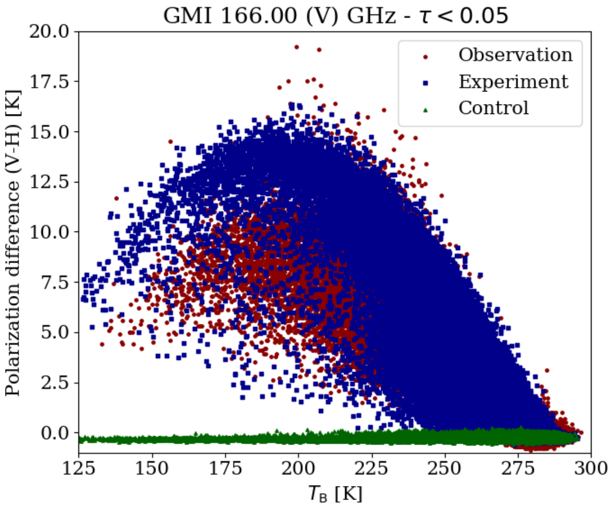
AR=1.22 (x=10%)

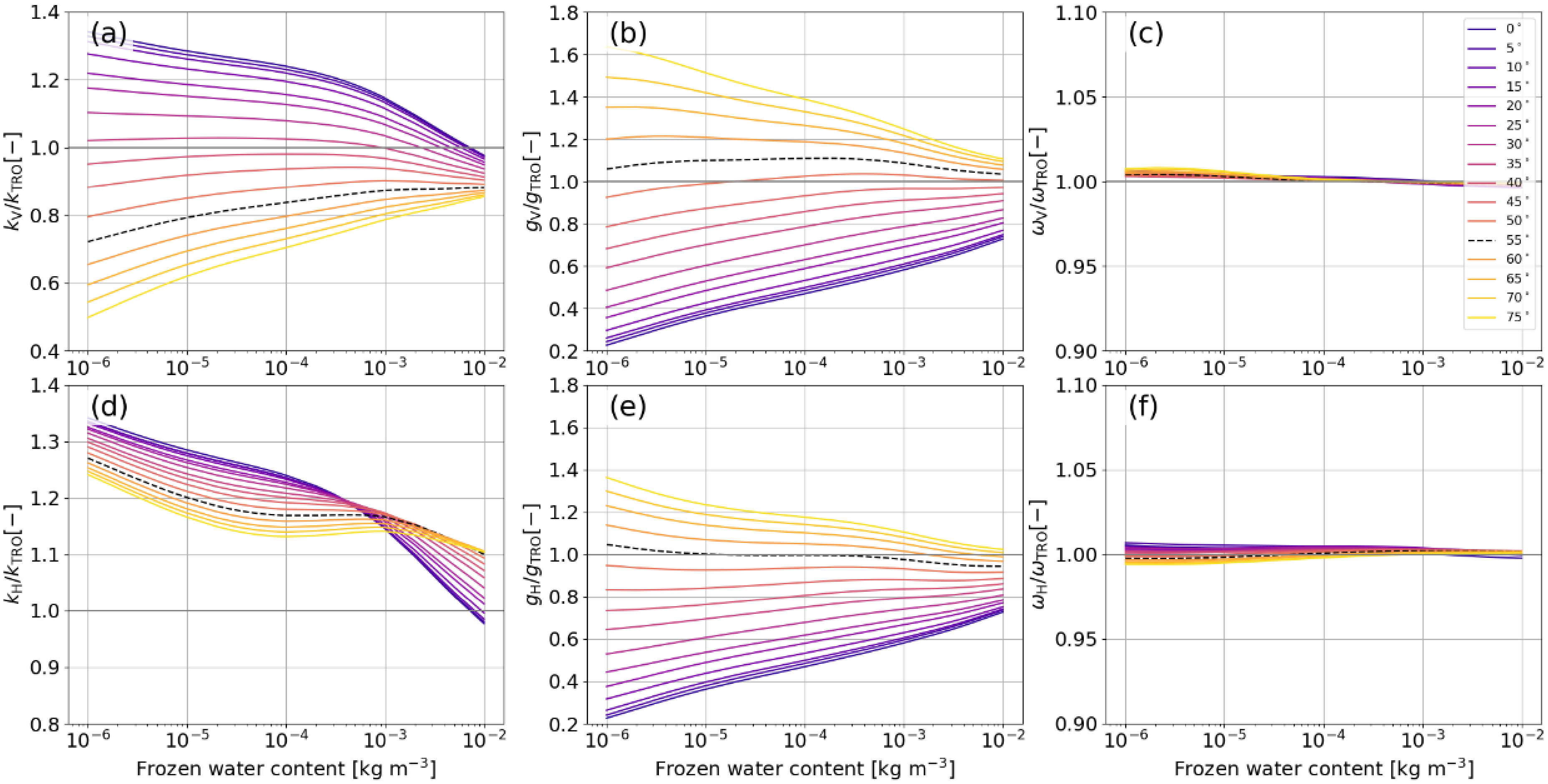


AR=1.3 (x=13%)



AR=1.4 (x=17%)





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Surface emissivity models in RTTOV

	RTTOV version	Linear regression	Neural Networks	Relative wind direction as input	Foam fraction an optional input	Reflectivity calculated (not set to 1 – ε or zero)	Spectral coverage (GHz)
FASTEM-3	8.0	✓		✓		✓	20 - 60
FASTEM-4	10.0	✓		✓	✓	✓	1.4 - 410
FASTEM-5	10.2	✓		✓	✓	✓	1.4 - 410
FASTEM-6	11.2	✓		✓	✓	✓	1.4 - 200
TESSEM2	12.0		✓				1.4 - 700
SURFEM OCEAN	13.2		✓	✓		✓	0.5 - 700

- Relative wind direction added
- All science updated: permittivity, surface roughness and foam
- Foam model reverted to FASTEM-3
- Relative wind direction reverted to FASTEM-4

Relative wind direction added. More neurons.

$$relative\ wind\ direction = satellite\ azimuth - wind\ direction$$

Thanks to Emma Turner

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UV simulations

Basic capability, to be developed.

Cloud, aerosol and Rayleigh scattering via DOM solver.

Improvements to be investigated:

- gas absorption
- polarisation
- fast scattering via MFASIS-NN

Comparison of RTTOV and DISAMAR for GOME-2 with Rayleigh multiple scattering

Thanks to Ping Wang and Olaf Tuinder

https://nwp-saf.eumetsat.int/publications/vs_reports/nwpsaf-ec-vs-062.pdf