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Evaluation of the fast visible RT model RTTOV-MFASIS and use for model cloud validation of ICON

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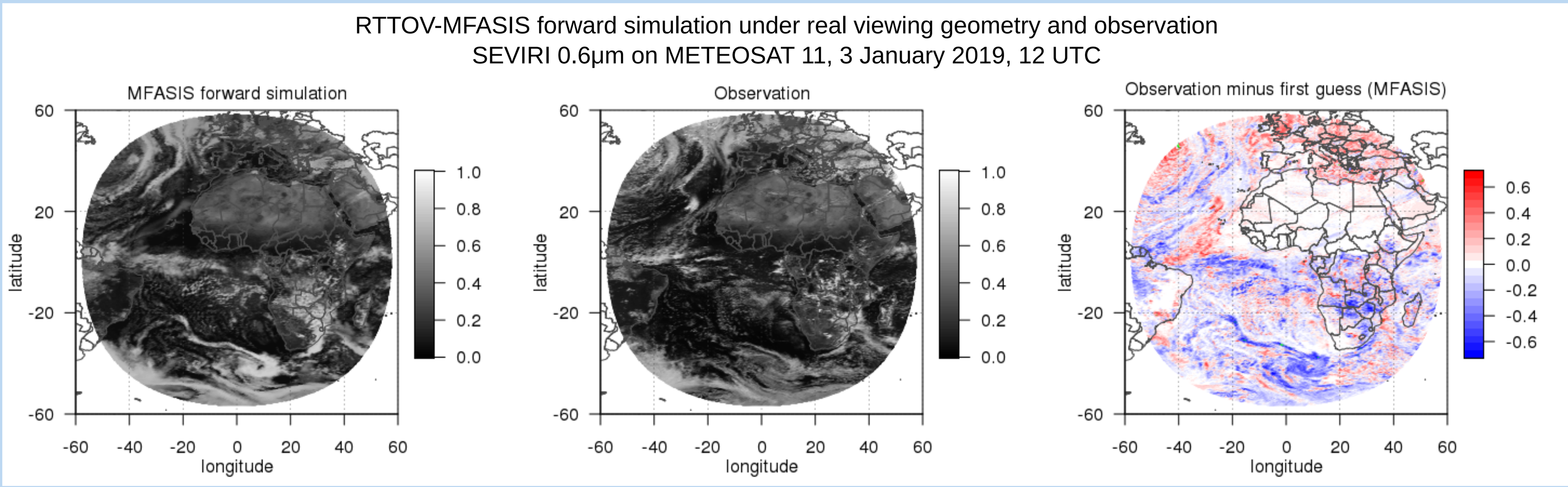
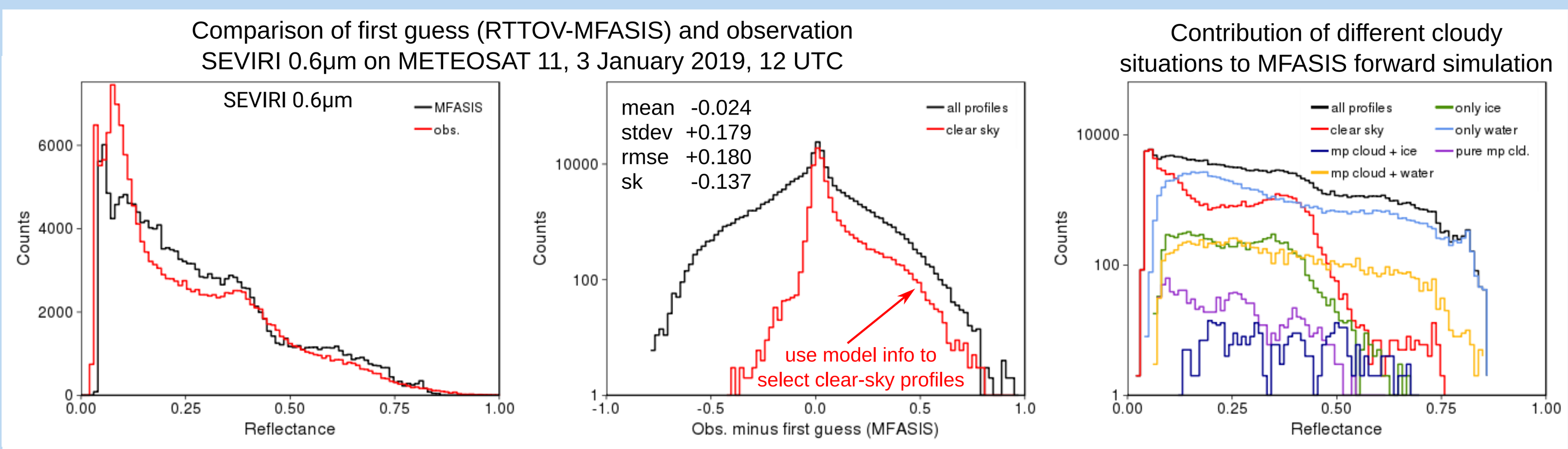
This work studies the fast RT method MFASIS for the simulation of visible satellite images available in RTTOV v12.2 and later versions. MFASIS is a lookup-table (LUT) based method (see L. Scheck et al., 11p.07). The LUTs are trained using the more accurate, 1D RT method RTTOV-DOM and are provided for SEVIRI, ABI and AHI via www.nwpsaf.eu. Here, we evaluate RTTOV-MFASIS results for the visible SEVIRI channels based on global ICON model fields by comparing them to RTTOV-DOM results in a suitable test setup and to SEVIRI observations. These investigations pave the way for further updates to MFASIS and the validation of model cloud fields. First data assimilation experiments using MFASIS in convection-resolving models have demonstrated its value by improving the representation of cloud cover and precipitation (see L. Scheck et al., 11p.07; L. Bach et al., 9.04).

1 Comparison of simulated and observed reflectances

Reflectance based on ICON forward simulation (left) shows similar cloud patterns as observation (middle). Largest errors occur where model cloud fields differ (right). Less cloud struture is visible in the model equivalent because the MFASIS forward simulation lacks 3D RT effects, e.g., due to cloud-top inclination (see L. Scheck et al., 11p.07). A correction to approximately account for cloud-top inclination in MFASIS is planned for RTTOV v13.



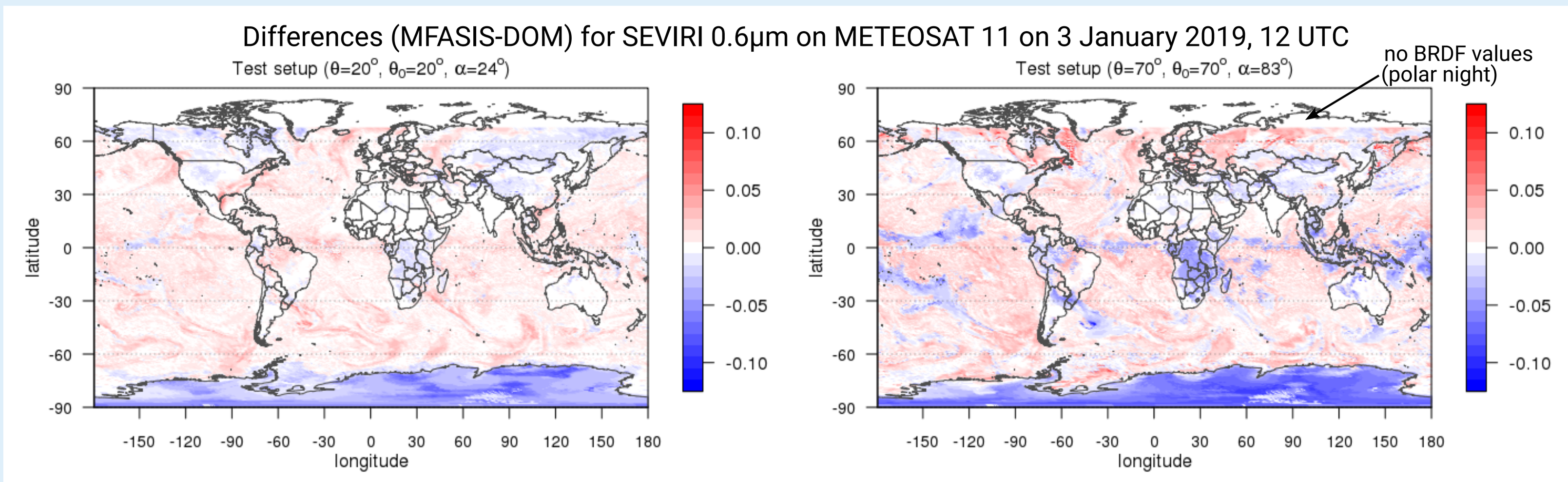
The reflectance histogram (left) shows that the overall shape of the observed reflectance curve is reproduced in model calculations. Observation minus first guess departures (middle) exhibit a Gaussian shape, with clear-sky contributions promoting a peak around the mean. Contributions from different atmospheric situations are quantified (right). Here, the model equivalents have been classified by applying thresholds on the total ice and water optical depths in the vertical profile.



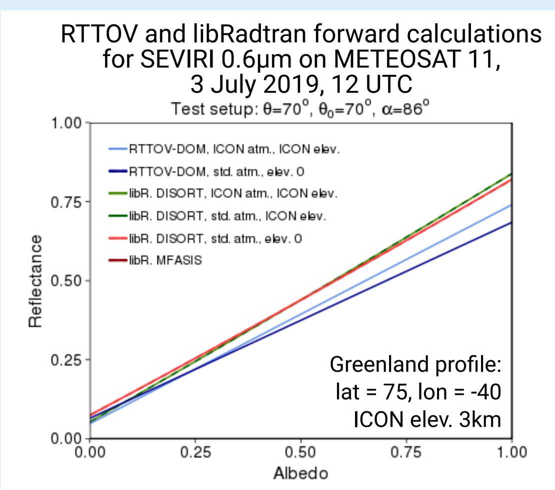
2 Evaluation: RTTOV-MFASIS versus RTTOV-DOM

Differences between model forward simulations are due to forward-operator assumptions, error dependence on viewing geometry, characteristics of the atmospheric profiles, NWP model quality and observation errors. In order to nail down the error sources, we evaluate the RTTOV-MFASIS forward operator in a **test setup**: We compare forward simulations using ICON model fields for 180.000 atmospheric profiles on a generic latitude-longitude grid with fixed satellite-sun viewing geometry to RTTOV-DOM results.

Differences between reflectance from RTTOV-MFASIS and RTTOV-DOM simulations depend on the viewing geometry and the properties of the atmospheric profiles. For the SEVIRI instrument, errors are typically larger for the 0.8µm channel.



2.1 Large MFASIS-DOM differences over Antarctica (winter) and Greenland (summer)

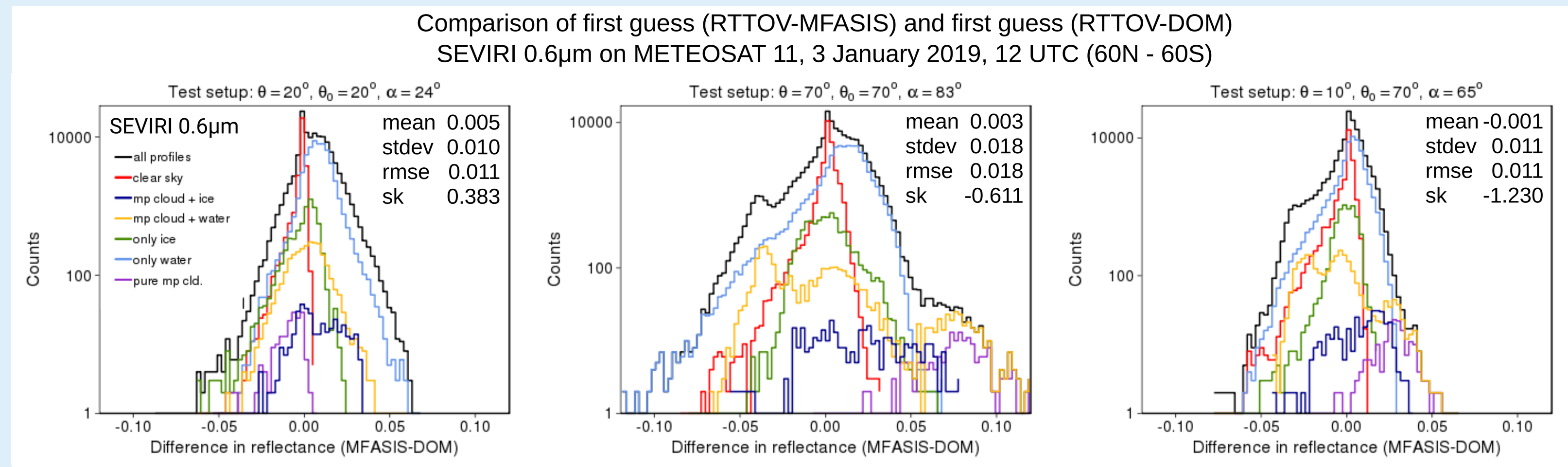


Antarctica and Greenland are characterised by large albedos and high terrain. The assumption that all terrain is at elevation 0m in MFASIS (elevation is set to 0m in the LUT training) in combination with large albedos leads to large differences between RTTOV-MFASIS and RTTOV-DOM reflectances due to missing multiple Rayleigh scattering processes in RTTOV-DOM (and in MFASIS LUTs). Errors are significantly reduced in the respective libRadtran-DISORT/-MFASIS calculations, which account for multiple scattering processes.

RTTOV v13 will include multiple Rayleigh scattering. Until then, regions of high terrain and large albedos can be flagged. The current evaluation restricts profiles to latitudes 60N - 60S.

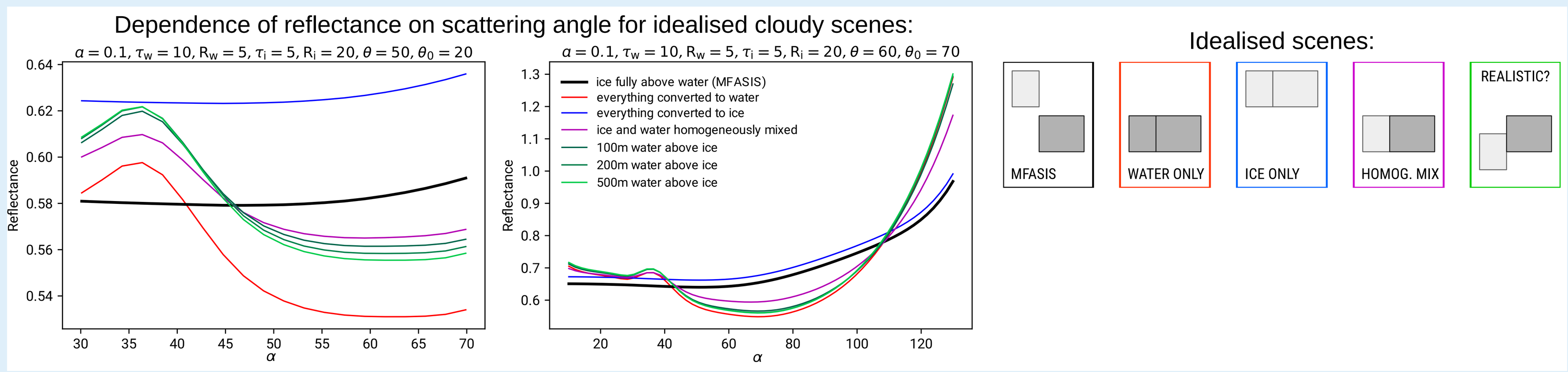
2.2 Dependence of MFASIS-DOM differences on cloudy situations

Reflectance differences obtained in RTTOV-MFASIS and RTTOV-DOM forward simulations and their dependence on atmospheric situations are shown below for a set of viewing geometries.
In order to categorise the model-field profiles into clear-sky, water-only, ice-only and mixed-phase cloud (pure, with ice above or water below mixed-phase cloud) situations, we introduce thresholds on the total ice and water optical depths in the vertical profiles.

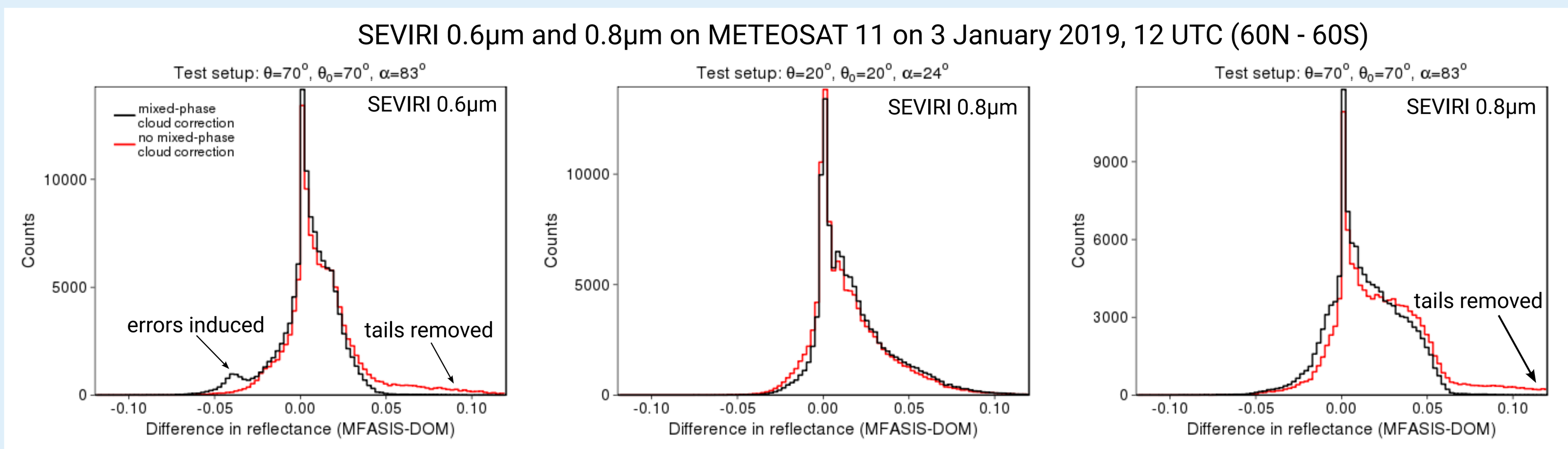


2.3 Empirical mixed-phase cloud correction

MFASIS assumes separate, homogeneous ice and water clouds at fixed height. However, ground-based and in-situ observations have shown that realistic mixed-phase clouds typically have a water-only layer on top of the ice-water composite. Based on the study of several idealised scenes, RTTOV-MFASIS applies a simple correction for mixed-phase clouds by using the effective ice and water optical depths $\tau^{\mathrm{i}}_{\mathrm{eff}} = \tau^{\mathrm{i}} - \tau^{\mathrm{i}}_{\mathrm{mixed}}, \tau^{\mathrm{w}}_{\mathrm{eff}} = \tau^{\mathrm{w}} + \tau^{\mathrm{i}}_{\mathrm{mixed}}$ for the forward simulation.

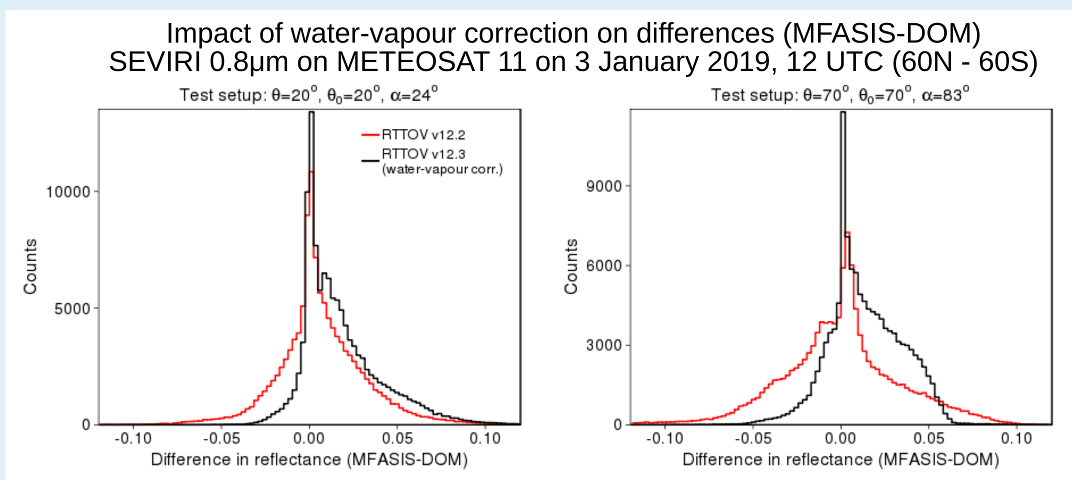


Reflectance differences in the RTTOV-MFASIS and RTTOV-DOM simulations illustrate that this simple mixed-phase cloud correction has an overall neutral to slightly positive impact. Work is ongoing to investigate improvements for mixed-phase cloud situations.



2.4 Linear water-vapour correction

The SEVIRI 0.8µm channel is sensitive to water vapour in the atmosphere. RTTOV v12.3 applies a linear correction that accounts for cloud-top heights and water-vapour profiles not considered during the LUT generation. The correction successfully reduces errors in the SEVIRI 0.8µm channel to the same magnitude as other channels.



3 Outlook

- Future updates to RTTOV-MFASIS: Further improve mixed-phase cloud correction, account for some 3D RT effects (approximation for cloud-top inclination), include multiple Rayleigh scattering processes by updating LUTs using RTTOV-DOM (RTTOV v13) for LUT training
- Extend MFASIS to account for more RT effects and more particle species (aerosols)
  → Use neuronal network instead of lookup table (see L. Scheck et al., 11p.07)
- Validation of ICON and ICON-LAM (limited-area version of ICON, in preparation) using visible channel information in conjunction with all-sky infrared simulations
- Assimilation of visible satellite observations in global and convection-resolving models

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