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

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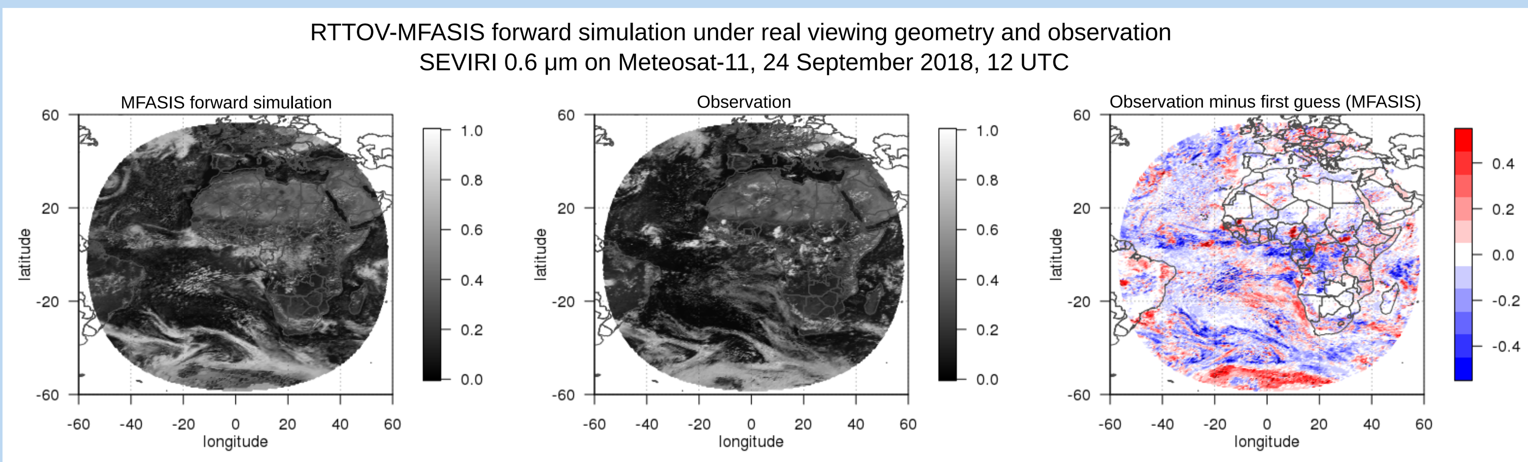
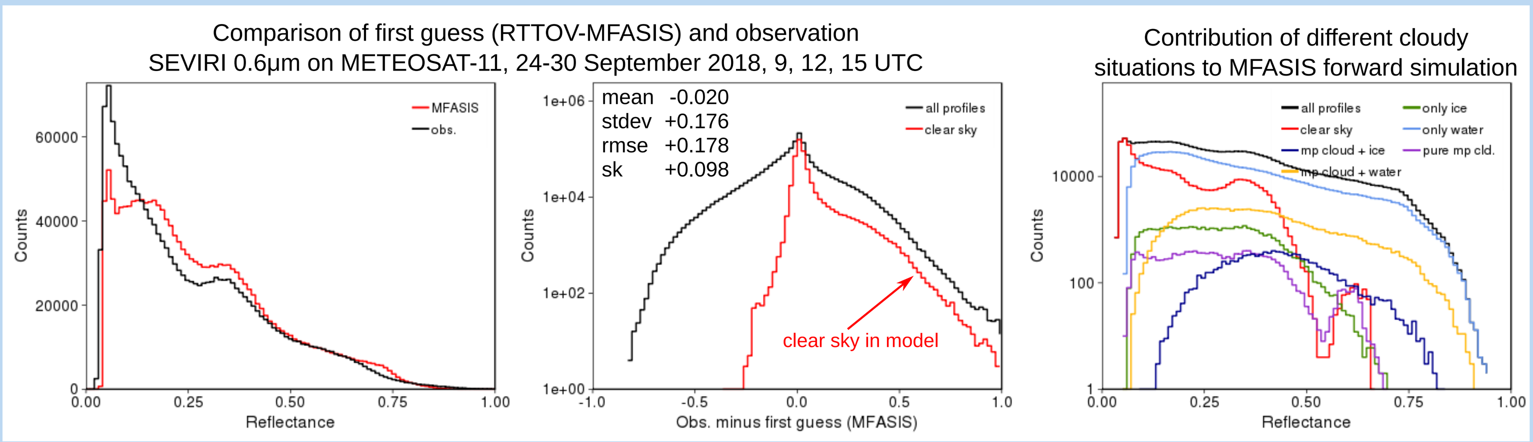
This work studies the fast RT method MFASIS for the simulation of visible satellite images available in RTTOV v12.2 and later versions. MFASIS is a lookup-table (LUT) based method. The LUTs are trained using the more accurate, 1D RT method RTTOV-DOM and are provided for SEVIRI, ABI and AHI via www.nwpsaf.eu. 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.

1 Comparison of simulated and observed reflectances

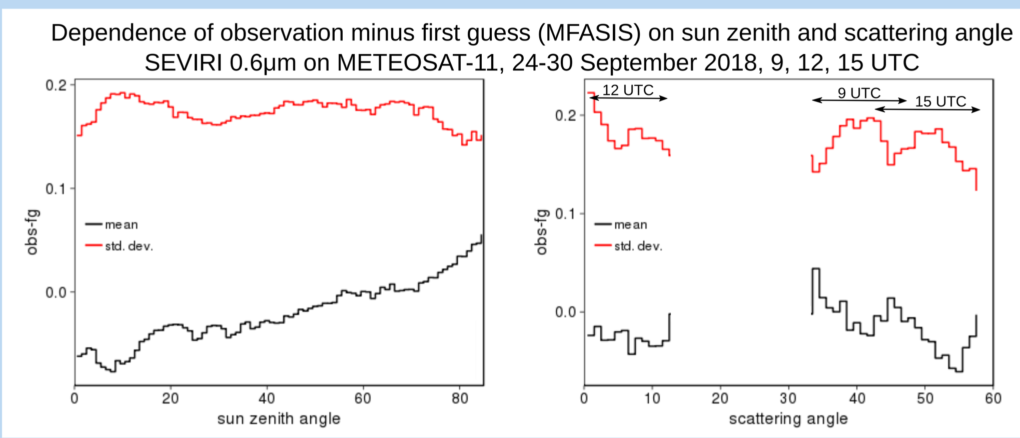
Idea: Compare RTTOV-MFASIS forward simulations based on global ICON model fields to visible channel observations for the experimental period 24-30 September 2018 (hourly forecasts), offering a large variety of atmospheric situations and at different local times



- Simulated reflectance (left) shows similar cloud patterns as observation (middle)
- Largest errors occur where model cloud fields differ (right)
- Less cloud structure visible in model equivalent due to lacking 3D RT effects, e.g., due to cloud top inclination → Correction for approximate cloud top inclination is planned for RTTOV v13



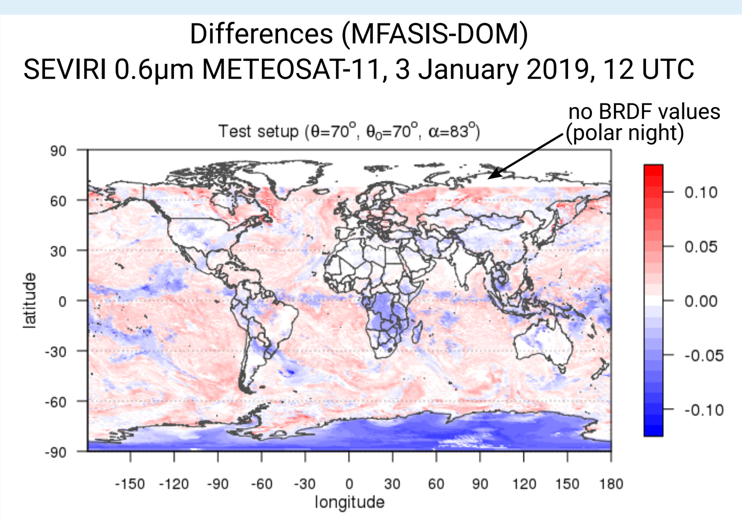
- Overall shape of the observed reflectance is reproduced in model calculations (left)
- Observation minus first guess departures exhibit Gaussian shape, with clear-sky contributions promoting a peak in the mean (middle)
- Contributions from different atmospheric situations to reflectance histogram (right)



- Approx. linear dependence of first guess departures on sun zenith (left) → bias correction?
- Larger errors expected in dependence of first guess departures on scattering angle in backscatter and cloud-bow region (right)
- To Do: Study effects of different cloud types and surface albedos; collect more statistics

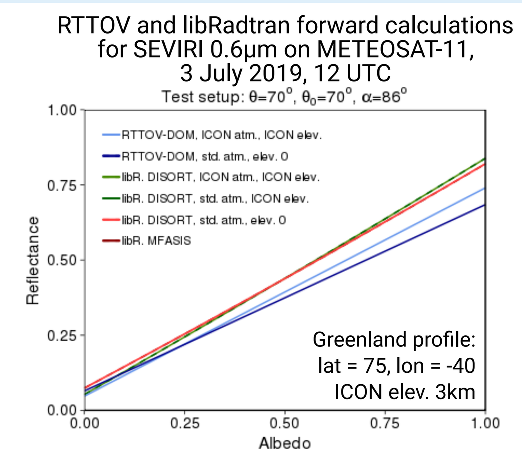
2 Evaluation: RTTOV-MFASIS versus RTTOV-DOM

Evaluate RTTOV-MFASIS forward operator in a **test setup** to identify systematic errors: 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 reflectances from RTTOV-MFASIS and RTTOV-DOM simulations depend on viewing geometry and properties of the atmospheric profiles
- SEVIRI: Errors are typically larger for the 0.8µm channel

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

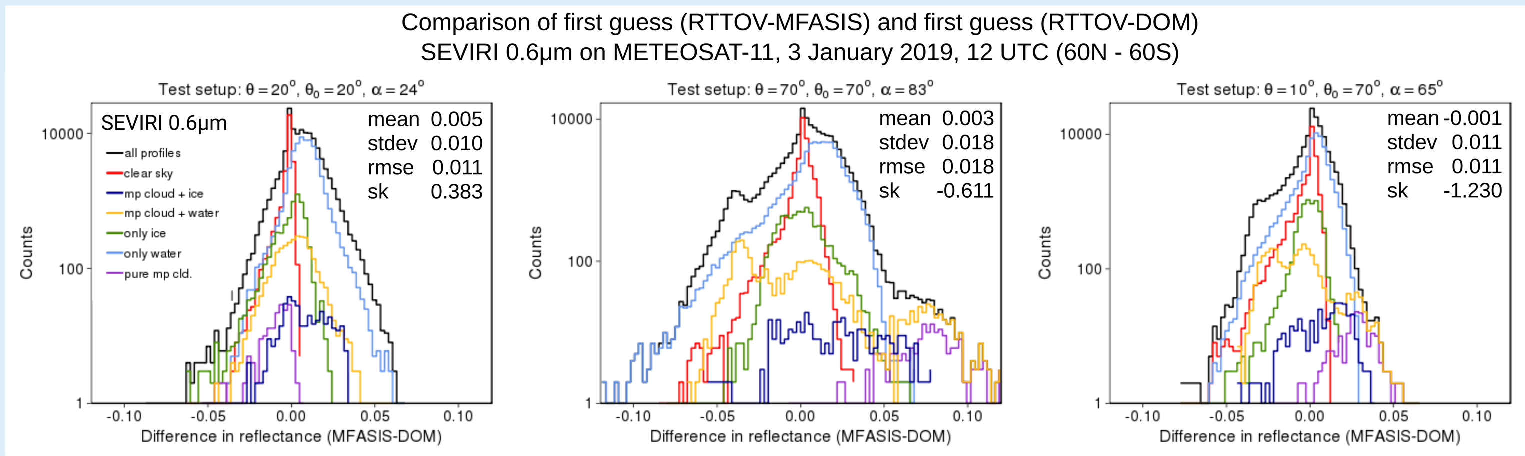


- Regions with high terrain and large albedo have large MFASIS-DOM differences because of missing multiple Rayleigh scattering processes in RTTOV-DOM (and in MFASIS LUTs)
- Errors significantly reduced in respective libRadtran-DISORT/-MFASIS calculations, which account for multiple scattering processes

→ RTTOV v13 includes multiple Rayleigh scattering
→ Currently: Flag regions of high terrain and large albedos

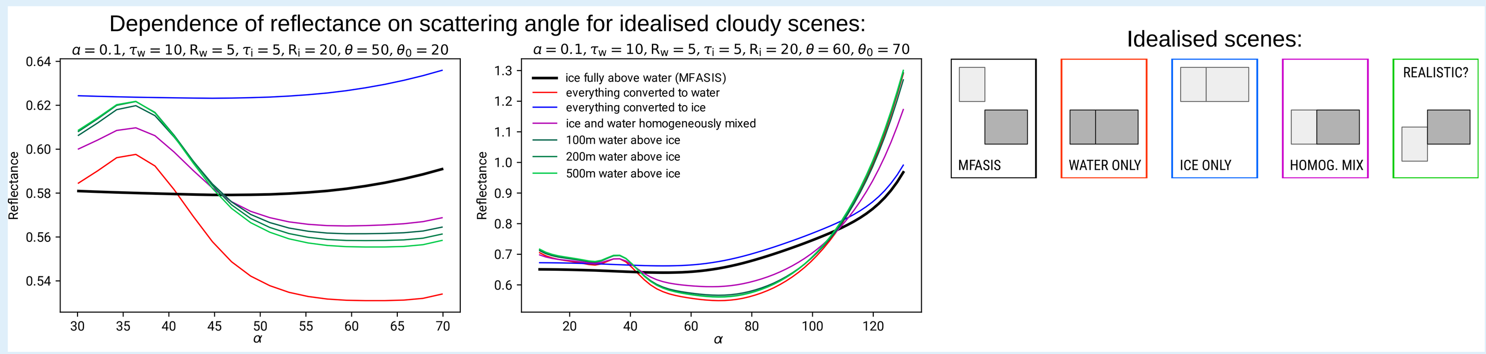
2.2 Dependence of MFASIS-DOM differences on cloudy situations

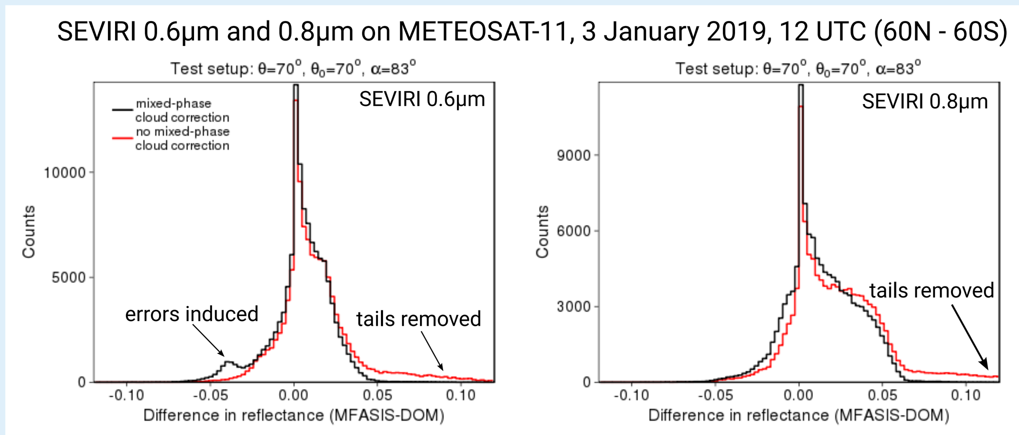
Introduce threshold on total ice and water optical depths to categorise model-field profiles to study reflectance differences obtained in RTTOV-MFASIS and RTTOV-DOM forward simulations and their dependence on atmospheric situations for different viewing geometries



2.3 Empirical mixed-phase cloud correction

- MFASIS assumes separate, homogeneous ice and water clouds at fixed height
- Ground-based and in-situ observations: realistic mixed-phase clouds can have a water-only layer on top of the ice-water composite
- Study idealised scenes to derive simple correction for mixed-phase clouds by using effective ice and water optical depths $\tau^i_{eff} = \tau^i - \tau^i_{mixed}$, $\tau^w_{eff} = \tau^w + \tau^i_{mixed}$ for the forward simulation

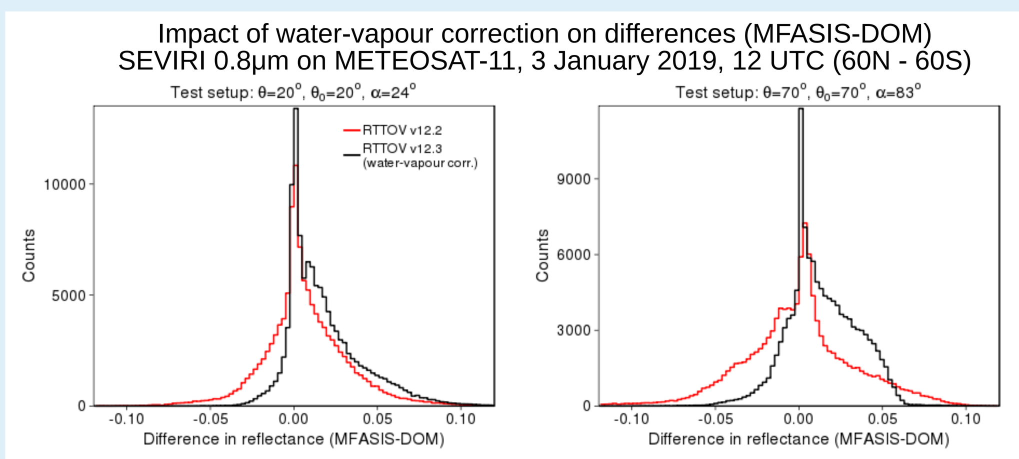




- Simple empirical mixed-phase cloud correction has overall neutral to slightly positive impact
- Work in progress to investigate improvements for mixed-phase cloud situations

2.4 Linear water-vapour correction

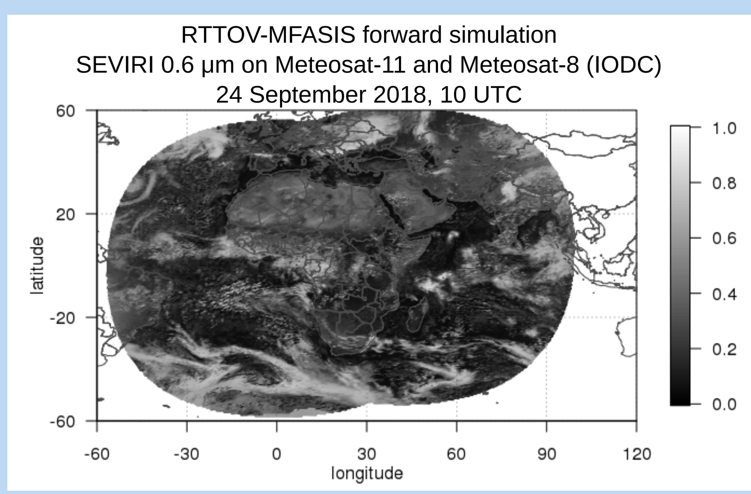
- SEVIRI 0.8µm channel is sensitive to water vapour in the atmosphere
- RTTOV v12.3 applies linear correction that accounts for cloud-top heights and water-vapour profiles not considered during LUT generation



→ Errors in SEVIRI 0.8µm channel successfully reduced to same magnitude as other channels

3 Outlook

- Work in progress on evaluating RTTOV-MFASIS forward simulations against observations:
  → Extend use of visible channel information to various imagers on board geostationary and polar orbiting satellites
  → Use of level-2 products to analyse results and systematic errors classified by cloud types
- Future updates to RTTOV-MFASIS: Further improve mixed-phase cloud correction, approximation for cloud-top inclination, include multiple Rayleigh scattering processes
- Extend MFASIS to account for more RT effects and more particle species (aerosols) → NNs
- 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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