

Evaluation of 3D and 1D Atmospheric Radiative Transfer using EarthCARE Data

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The analyses is based on radiative transfer (RT) simulations performed with the libRadtran RT library, using MYSTIC as the 3D RTM and DISORT as the 1D RTM. Model simulations were driven by input from EarthCARE Level 2b products ACM-COM, AM-ACD, and ALL-3D, and were evaluated against radiative flux datasets BMA-FLX and ACM-RT. All EarthCARE products use baseline BA.

Evaluation of simulated SW & LW TOA fluxes against EarthCARE products

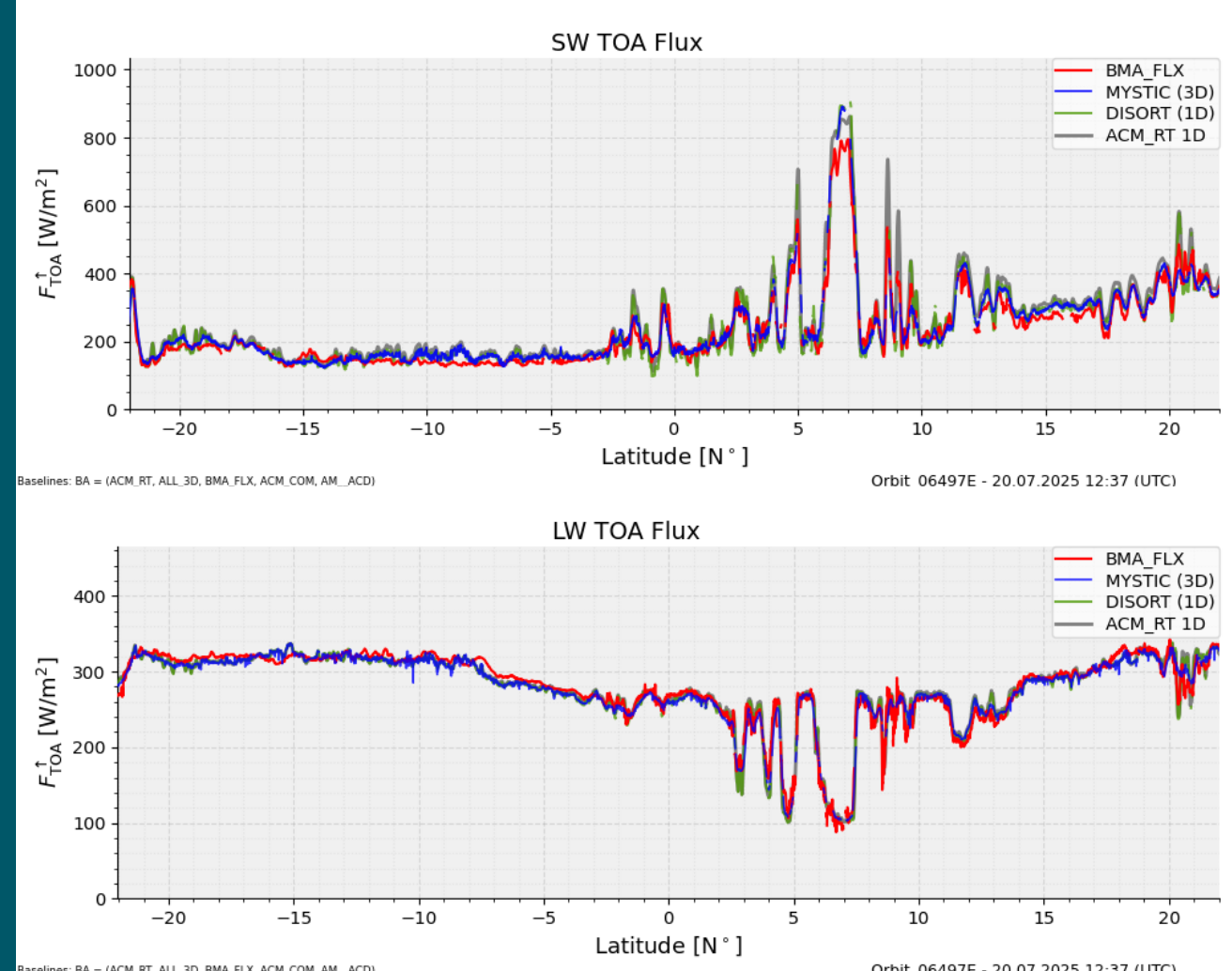


Figure 2: Comparison of simulated and measured TOA SW fluxes (upper panel) and LW fluxes (lower panel) for frame 06497E over Africa.

Eight frames were selected to study TOA SW and LW fluxes (Fig. 1). Figure 2 shows an example comparison between simulated fluxes (MYSTIC, DISORT, ACM-RT 1D) and observed fluxes (BMA-FLX) for Orbit 06497E.

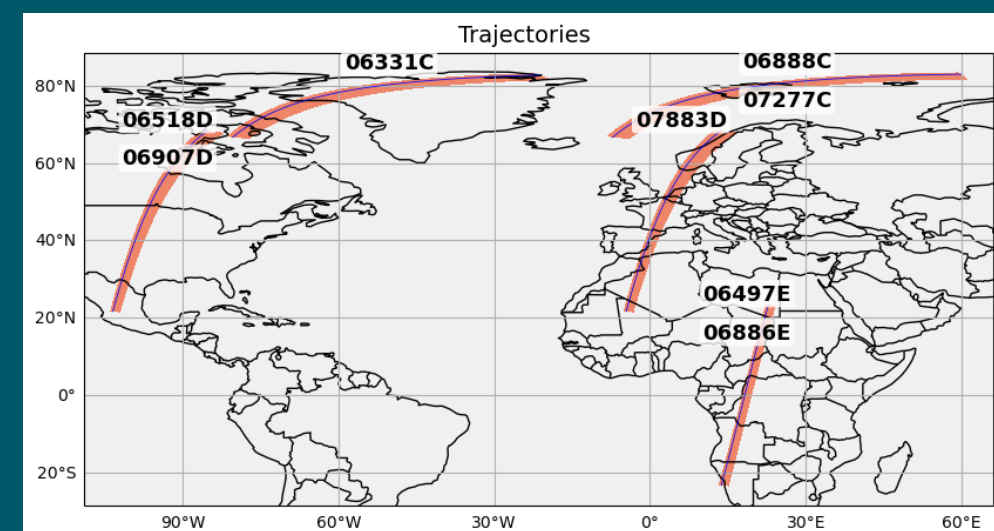


Figure 1: Eight frames used for TOA radiative flux assessment

SW biases are 3-5 W/m², while LW biases are about 1 W/m² for 3D and 1D models (Fig. 3)

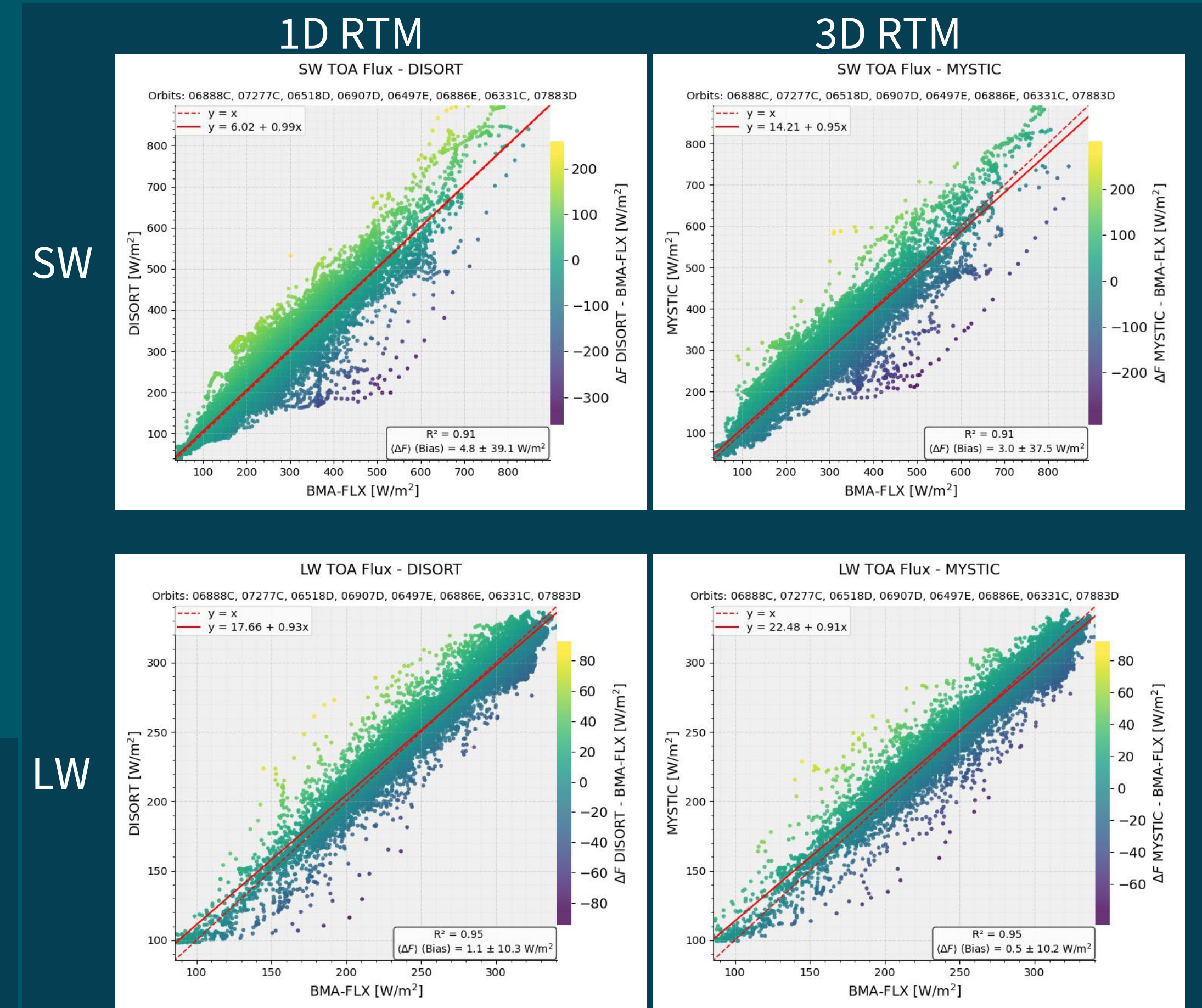


Figure 3: Correlation of 3D and 1D RTMs against BMA-FLX observations for eight frames (see Fig. 1)

Evaluation of surface radiation with ground-based observations

Surface SW downward fluxes were evaluated using 61 EarthCARE overpasses (daytime only, within ±5 pixels of the EarthCARE nadir-track, Jul. 2024-Oct. 2025)

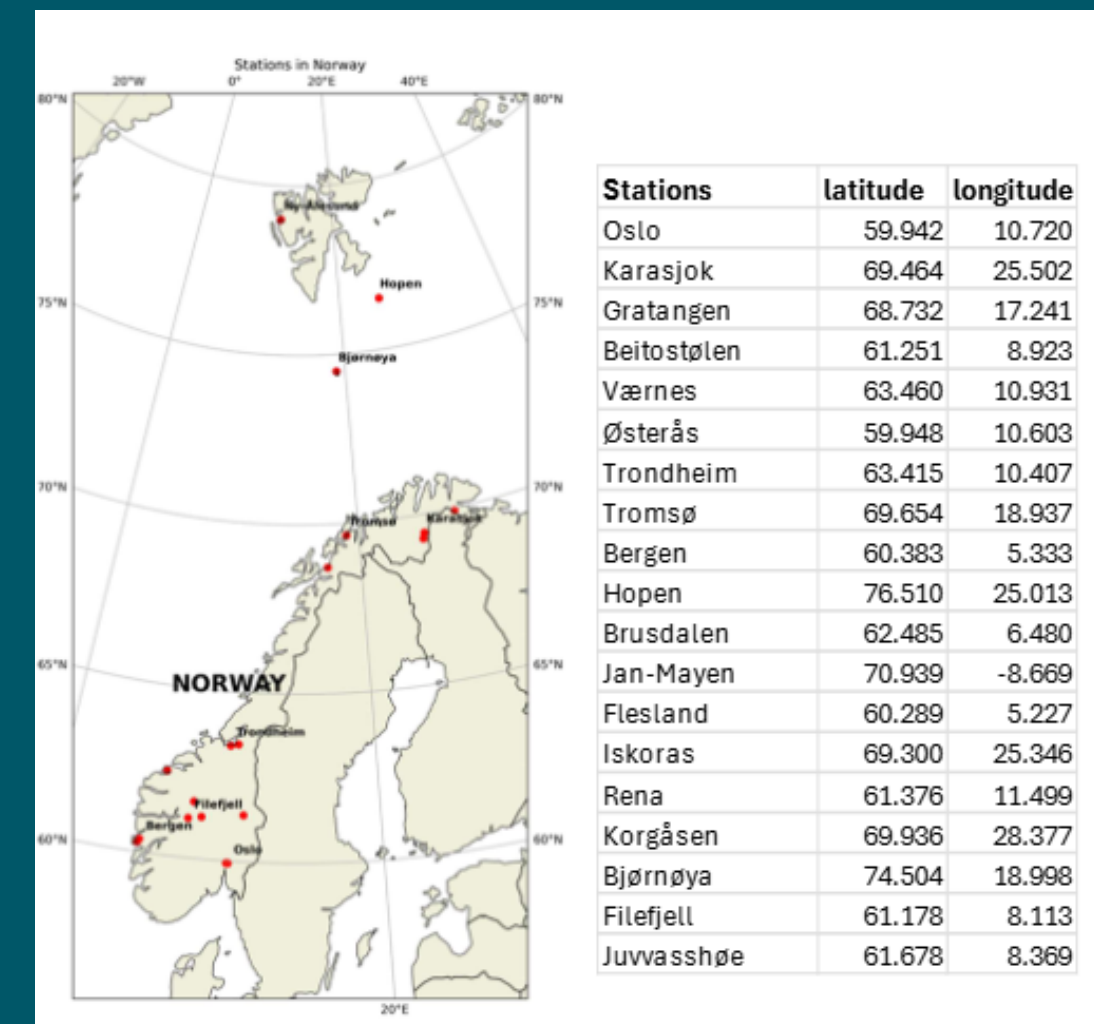


Figure 4: Stations with NRT Pyranometer data (300-2800 nm) available at seklima.met.no.

Surface observations are based on 19 ground-based (GB) stations across Norway (Fig. 4).

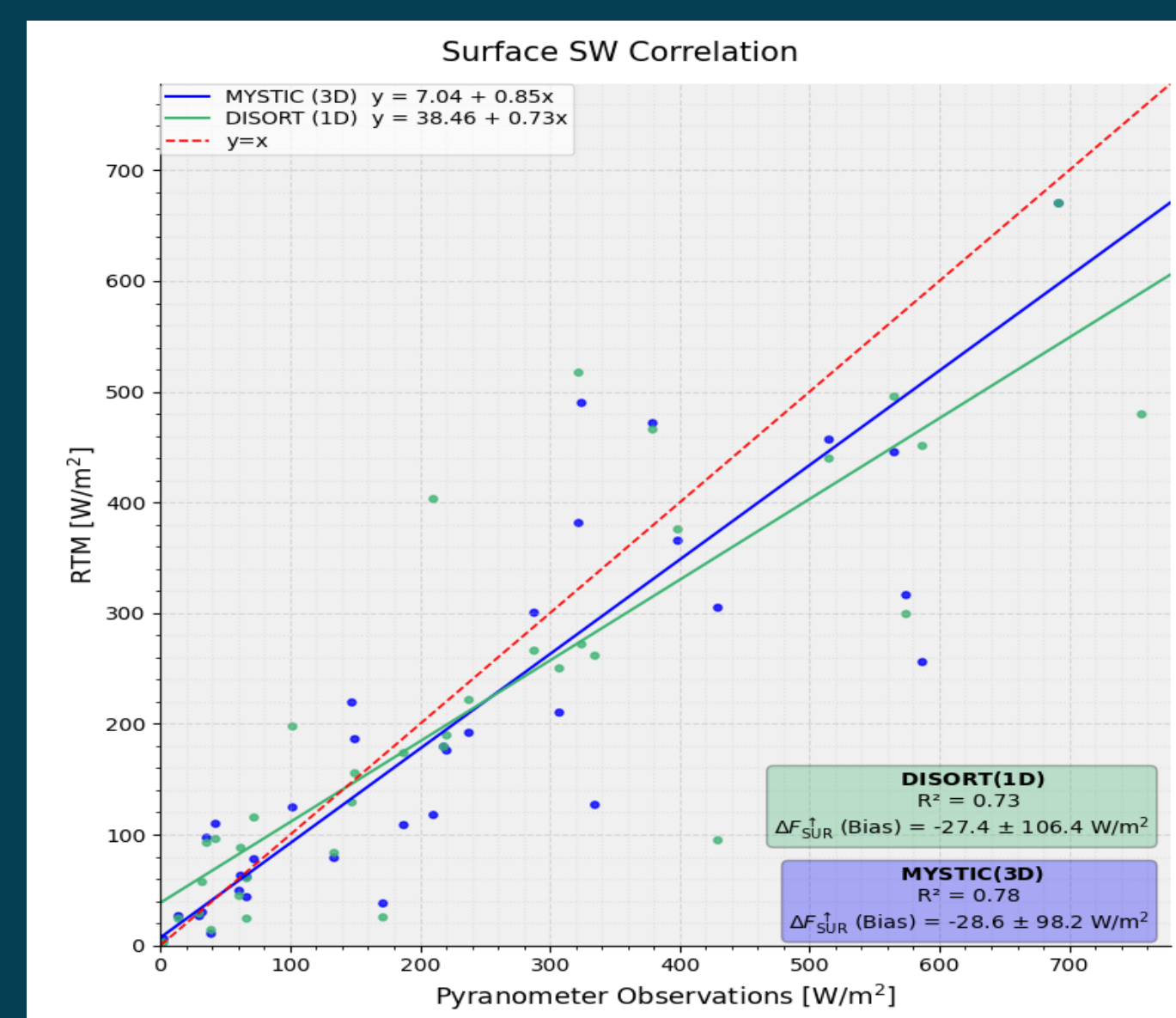


Figure 5: Correlation between simulated (3D and 1D RTMs) and observed surface SW downward fluxes.

Figure 5 shows general good agreement between GB observations and RTM simulations, but large variations in cloud cover, surface albedo, and topography make the comparison challenging.

Location	RTM	SW Bias [W/m ²]
Surface	MYSTIC (3D RTM)	-7 ± 96
	DISORT (1D RTM)	-26 ± 118
TOA	MYSTIC (3D RTM)	3 ± 45
	DISORT (1D RTM)	6 ± 56

Table 1: SW flux biases between 3D/1D RTM simulations and observations at the surface (pyranometers) and TOA (BMA-FLX). As shown in Tab. 1, simulated SW fluxes agree better with observations at TOA than at the surface.

TOA flux sensitivity to model assumptions

Ice crystal habits

Figure 6 shows simulated TOA SW flux differences between two ice habits: rough-aggregate (RA) and the general habit mixture (GHM). The habit-induced SW flux differences exceed 40 W/m², while the corresponding LW TOA flux differences are around 5 W/m².

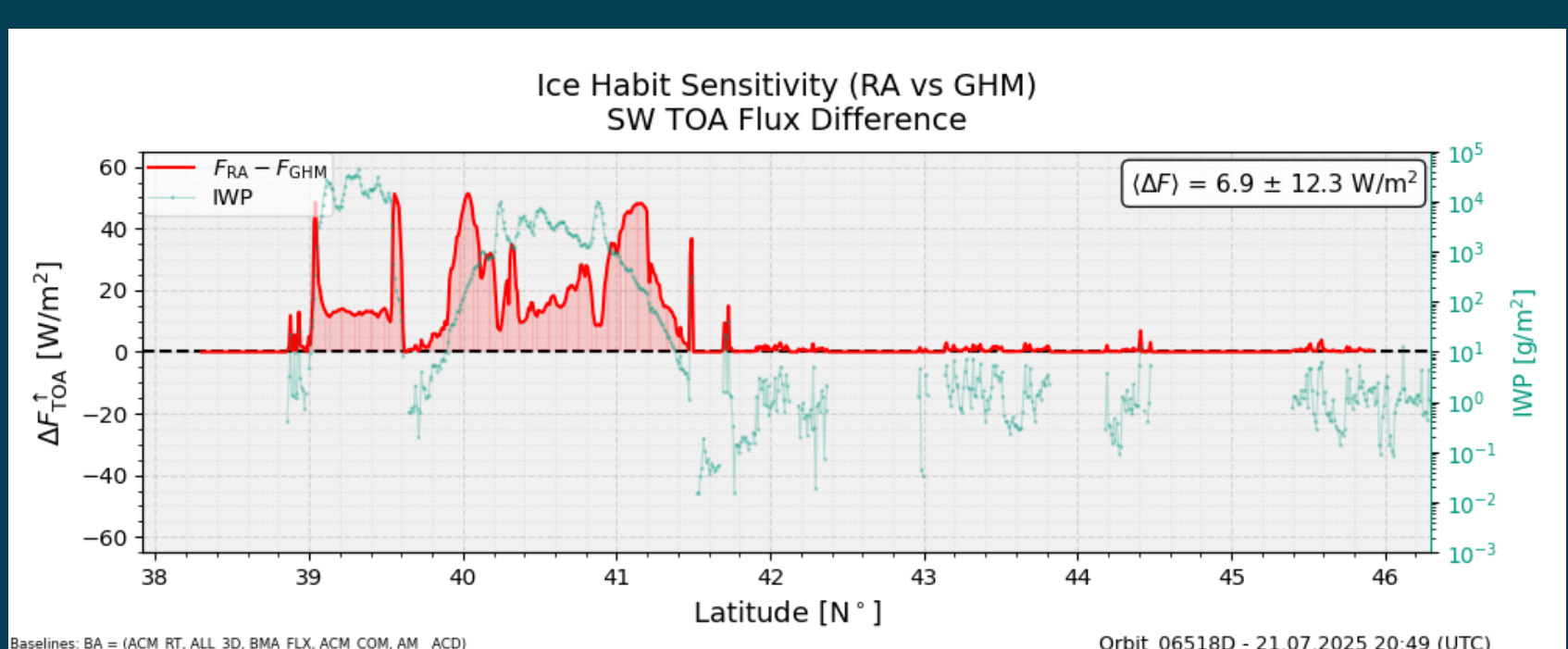


Figure 6: Differences in simulated SW TOA fluxes using different ice habits (RA: rough-aggregate, GHM: general habit mixture)

Aerosols

The LW response to aerosols have been investigated. Figure 7 shows TOA LW flux differences between simulations with aerosols in the LW region and simulations without aerosols.

The flux response closely follows the LW AOD distribution in the lower panel of Fig. 7, with local LW deviations exceeding 25 W/m².

The target classification for the same frame (Fig. 8) shows certain coarse-mode absorbing aerosols such as dust (purple) and ash (gray).

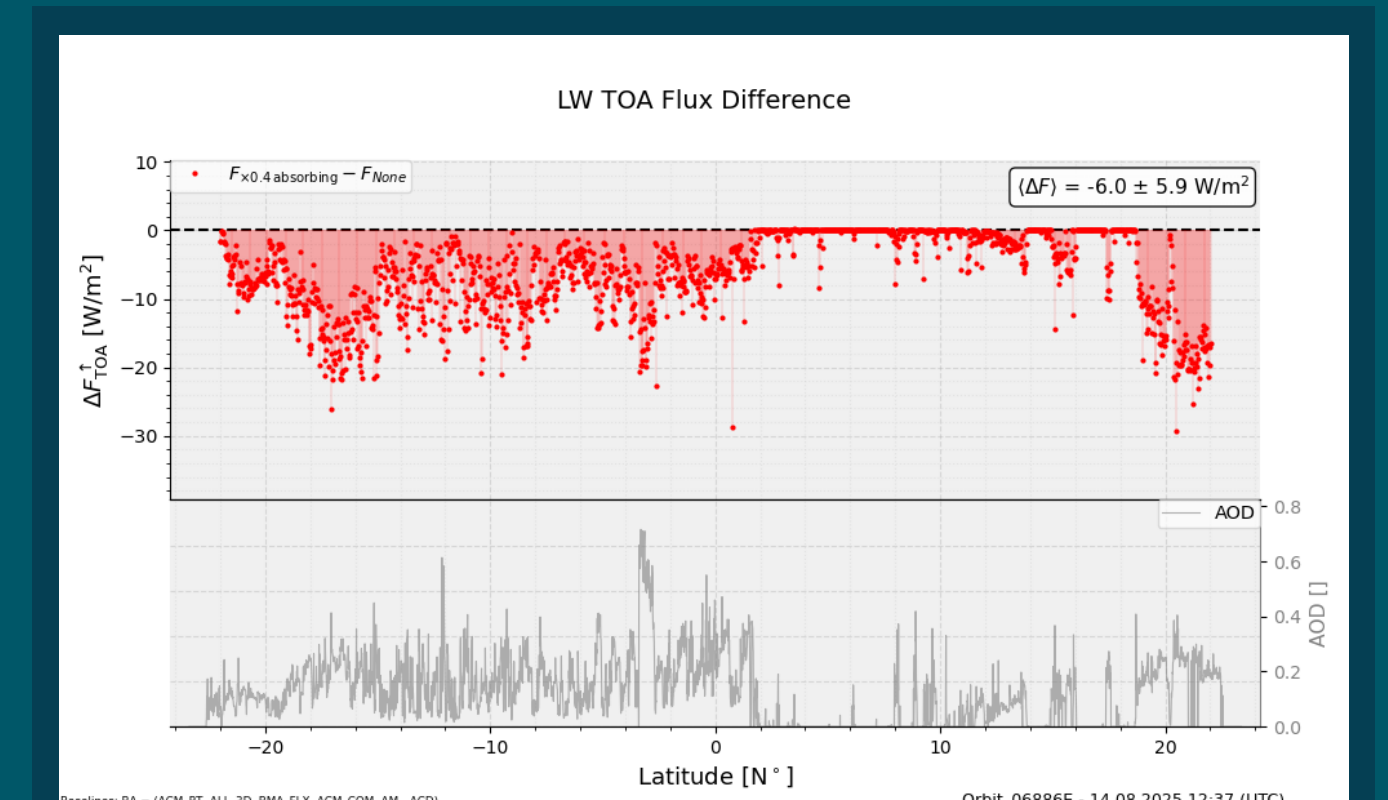


Figure 7: Difference in simulated LW TOA flux between prescribed AOD and no aerosol.

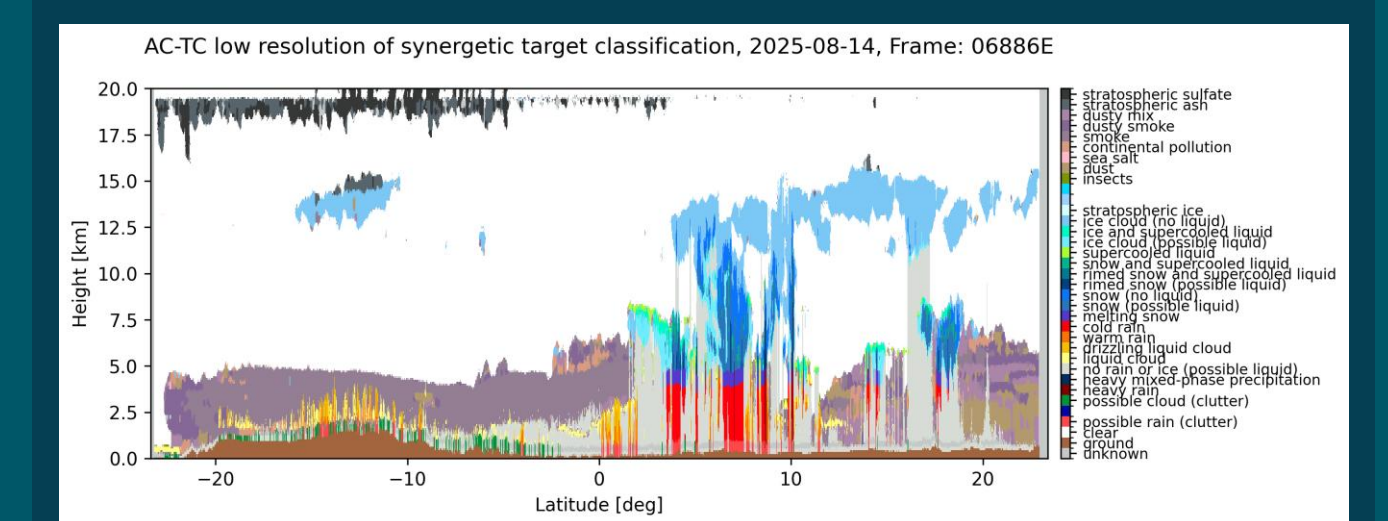


Figure 8: Target classification (TC) for the frame in Fig. 7.

3D Effects

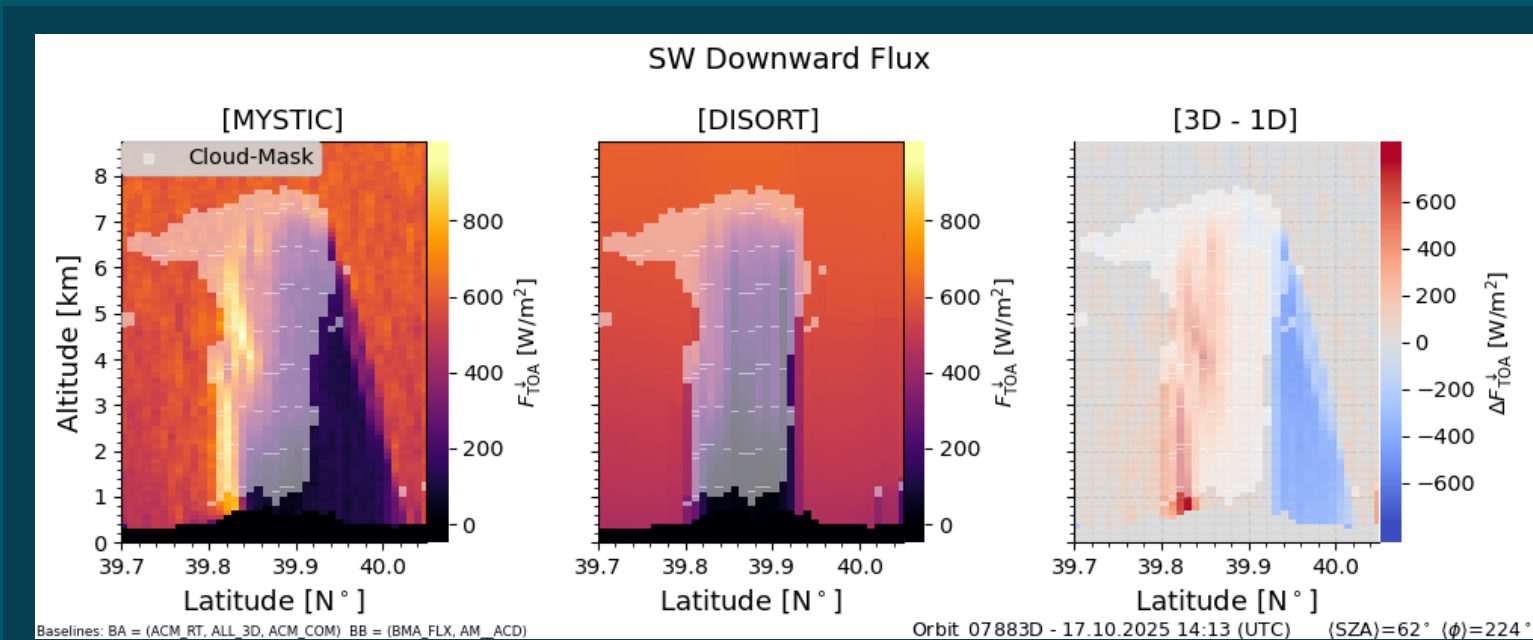


Figure 9: Downward SW flux fields from MYSTIC and DISORT, and their difference, showing local 3D effects.

Inclusion of horizontal RT in the 3D models produces local flux (F) deviations compared to the 1D approximation. These deviations are quantified using the 3D effect:

$$3D \text{ effect} \equiv F_{3D \text{ RTM}} - F_{1D \text{ RTM}}$$

Figure 9 shows 2D nadir views of downward SW flux from MYSTIC and DISORT, together with the 3D-1D difference. The figure shows cloud-side illumination and slanted shadows extending about 13 km northward.

Key takeaway

- Good agreement between BBR observations and libRadtran simulations for both SW and LW fluxes (Fig. 3)
- Local 3D cloud effects are clearly visible in cloudy scenes, while area-averaged 3D-1D differences remain small: 1.8 W/m² in SW and 0.6 W/m² in LW (Figs. 3 and 9)
- Surface SW fluxes agree reasonably with observations (Fig. 5), but the dataset is limited. Flux closure is better at TOA than at the surface (Tab. 1)
- The sensitivity to aerosols and ice crystal habits shows the importance of correct input parameters to the RTMs (Figs. 6-8)