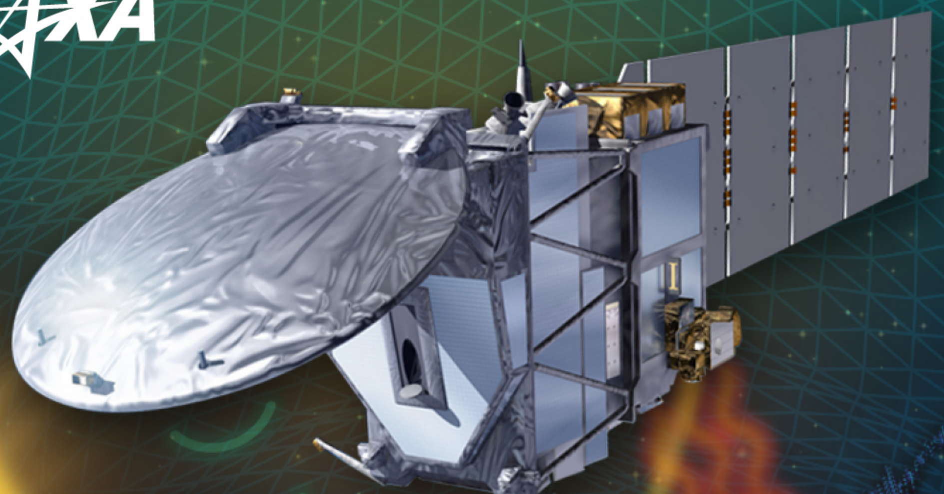

ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

Analysis of the radiation budget based on ground-based and satellite remote sensing observations in the Arctic

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Motivation

‘To achieve the objective, **the goal is that a retrieved scene** with footprint size of 10 km x 10 km **is measured with sufficiently high resolution** that the **atmospheric vertical profile of solar** and **terrestrial flux can be reconstructed with an accuracy of 10**Wm^{-2} **at the TOA**’ *[Wehr et al., 2023]*

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-To better understand the role of clouds on the climate system by investigating their radiative properties based on remote sensing observations.

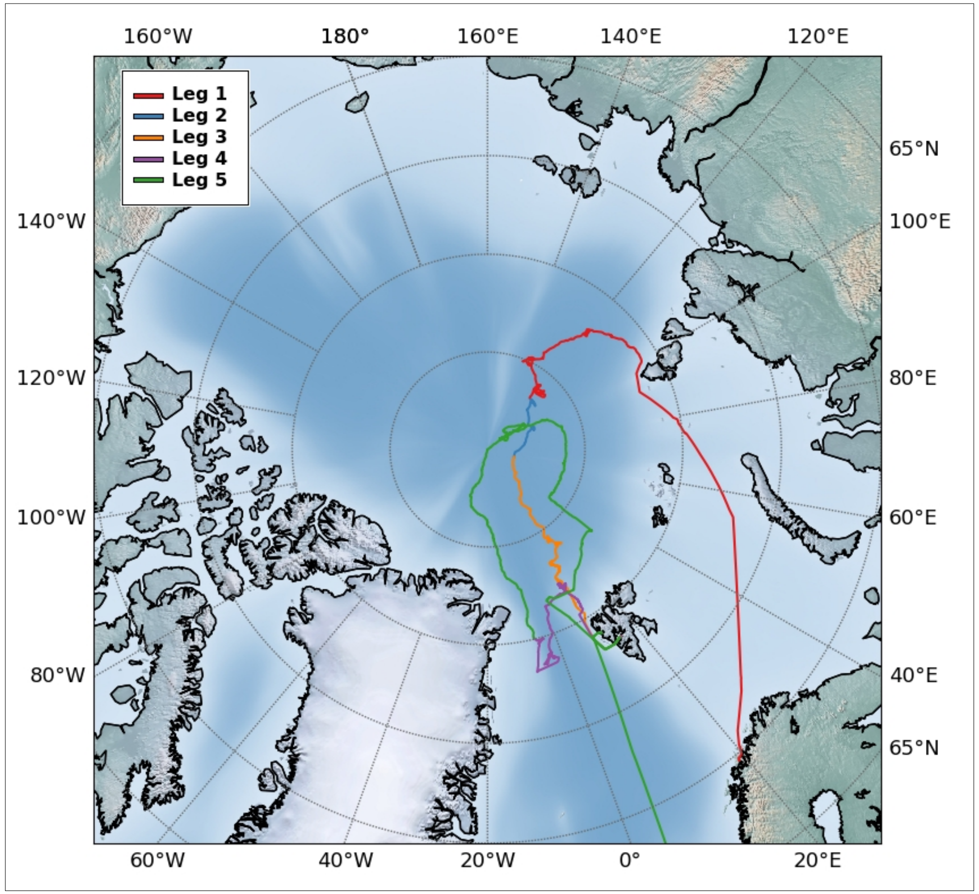
- Analyze ground-based and satellite remote sensing observations and products to quantify radiative biases and derive the radiation budget from two points of view.

- Focus on the unprecedented observations obtained during the Multidisciplinary drifting Observations for the Study of Arctic Climate (**MOSAiC**) expedition 2019-2020 and state of the art 1°x1° synergistic products from the Clouds and the Earth's Radiant Energy System (**CERES SYN**).

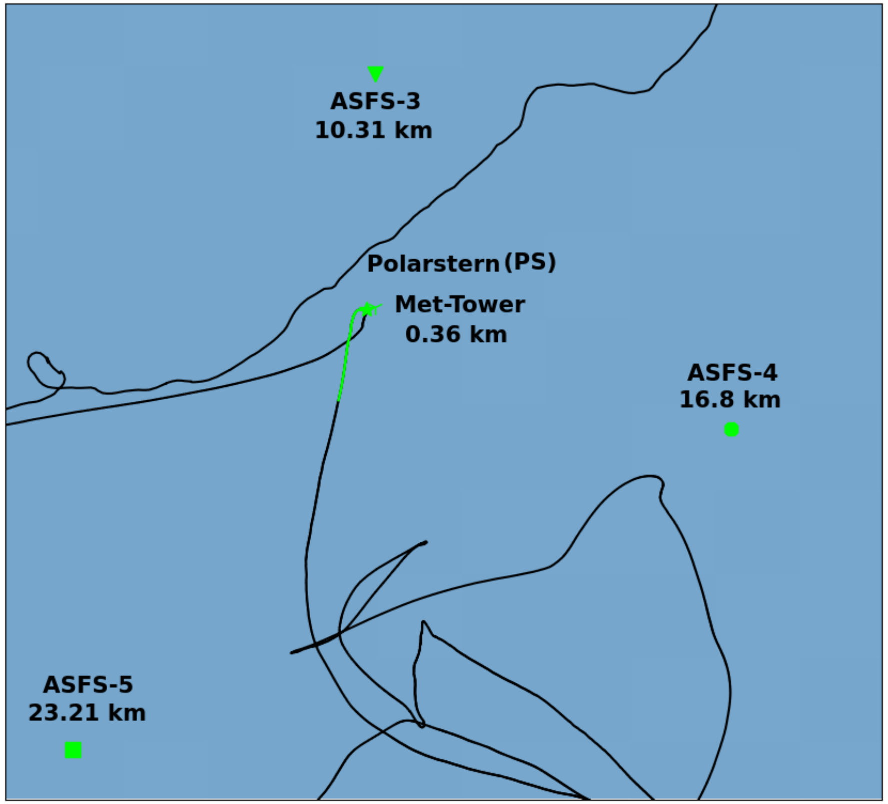
Datasets and Methodology

MOSAiC expedition

Start date: 2019-09-20 to 2020-10-12



Stations during MOSAiC (2020-01-19)



Distance to Polarstern (PS)

Automated Surface Flux Stations (ASFS)

Shipborne atmospheric remote sensing instrumentation

1	Raman Lidar Polly^{XT}	4	Laser Disdrometer
2	MWR HATPRO	5	2D Video Disdrometer
3	MWR MiRAC-P	6	Pyranometer + Pyrgeometer

7	KAZR cloud radar
8	Radiosondes

Adapted from H. Griesche

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Datasets and Methodology

ShupeTurner	CERES SYN
Micropulse Lidar Ceilometer KAZR cloud radar MWR HATPRO	The **SYN1degEd4.1** provides hourly values of upward and downward radiative fluxes at the BOA, and upward values at the TOA with a spatial resolution of 1°x1°
Cloud boundaries: Combined WACR + Micropulse lidar and ceilometer	Surface fluxes are computed with cloud properties derived by MODIS, Global Modeling Assimilation Office Global Earth Observing System GEOS-5 and MOA v 5.4
Interpolated merged radiosondes	Surface flux calculations are based on the Fu-Liou correlated-k 2/4 stream radiative transfer model

[Shupe et al., 2015, 2022]

[Minnis et al., 2021]

Datasets and Methodology

TROPOS **C**loud and **A**erosol **R**adiative effect **S**imulator (**T-CARS**)

[Hersbach et al., 2020]

ShupeTurner + Ancillary data ERA5 + 1D Radiative transfer model (RRTMG) = Radiative transfer simulations

1) Radiative closure (RC)

Radiative closure (RC) is a method used to **compare simulated radiative fluxes and observations** to understand the cloud macro and micro-physics retrievals better and potentially indicate where the sources of relevant uncertainty reside.

2) Cloud radiative effect (CRE)

Method used to quantify the **difference** between net radiative fluxes **for all-sky** atmospheric **conditions and** those **simulated** or observed in the **absence of clouds** for the same location and period.

$$CRE_x = (F_x^{\downarrow} - F_x^{\uparrow})_{all-sky} - (F_x^{\downarrow} - F_x^{\uparrow})_{clear-sky}.$$

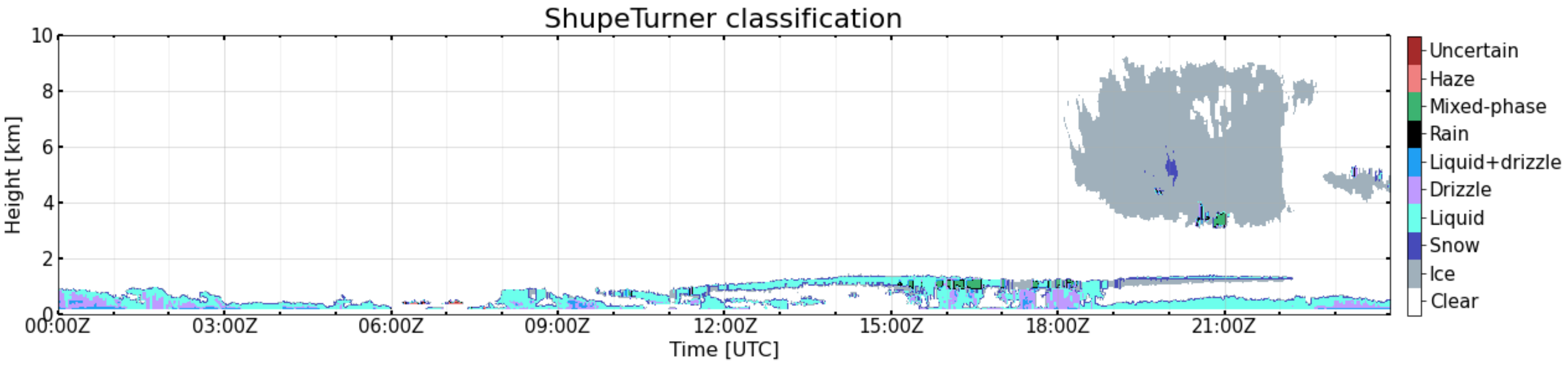
Shipborne and space borne comparison

The aim of the comparison is to improve our understanding of the role of clouds in the Arctic radiation budget and climate system.

Case study: 2020-07-13

Radiative flux comparison at the BOA

(Simulations - Observations)



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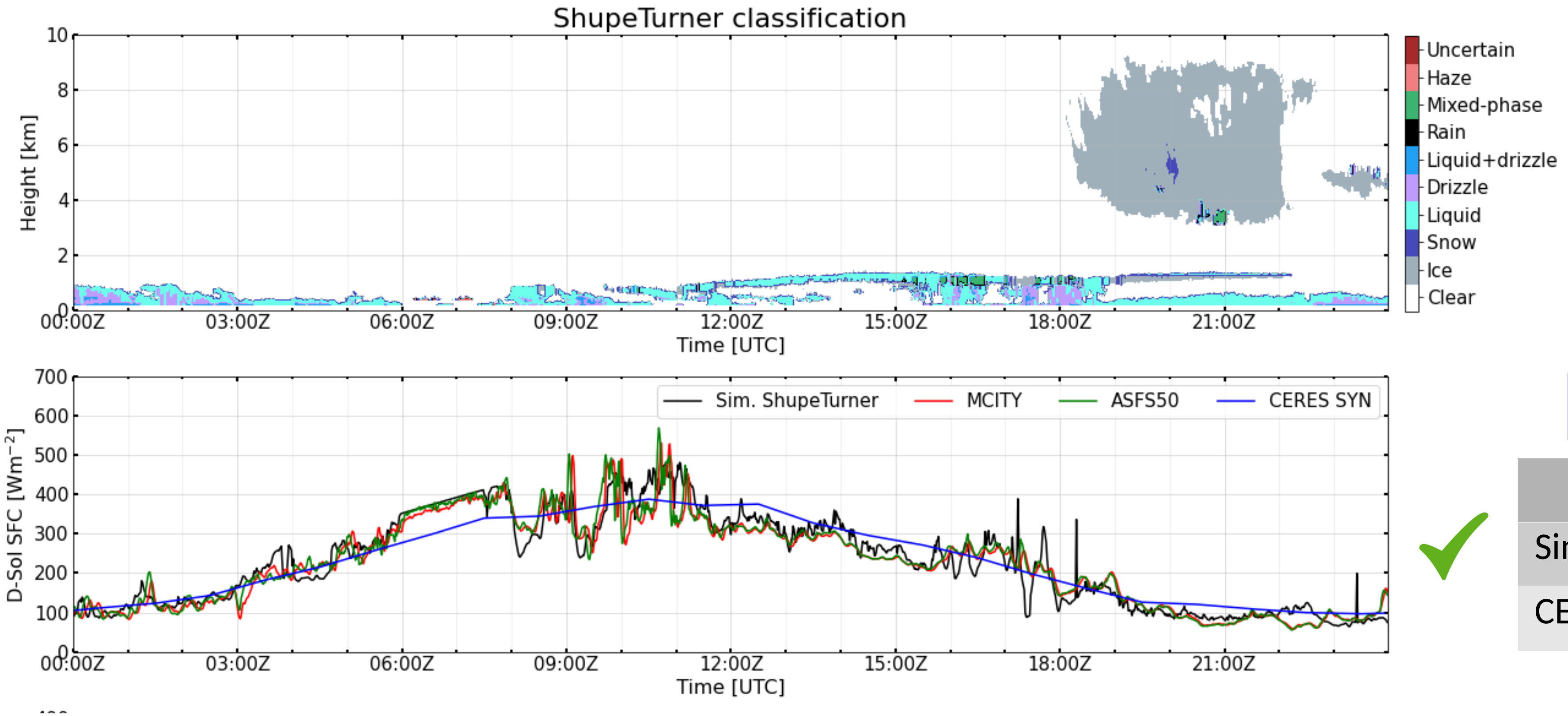
Radiative flux comparison at the BOA

(Simulations - Observations)



Downward Solar flux (D-Sol)

Bias [Wm^{-2}]	MCITY	ASFS50
Sim. ShupeTurner	6.9	4.5
CERES SYN	7.9	5.4

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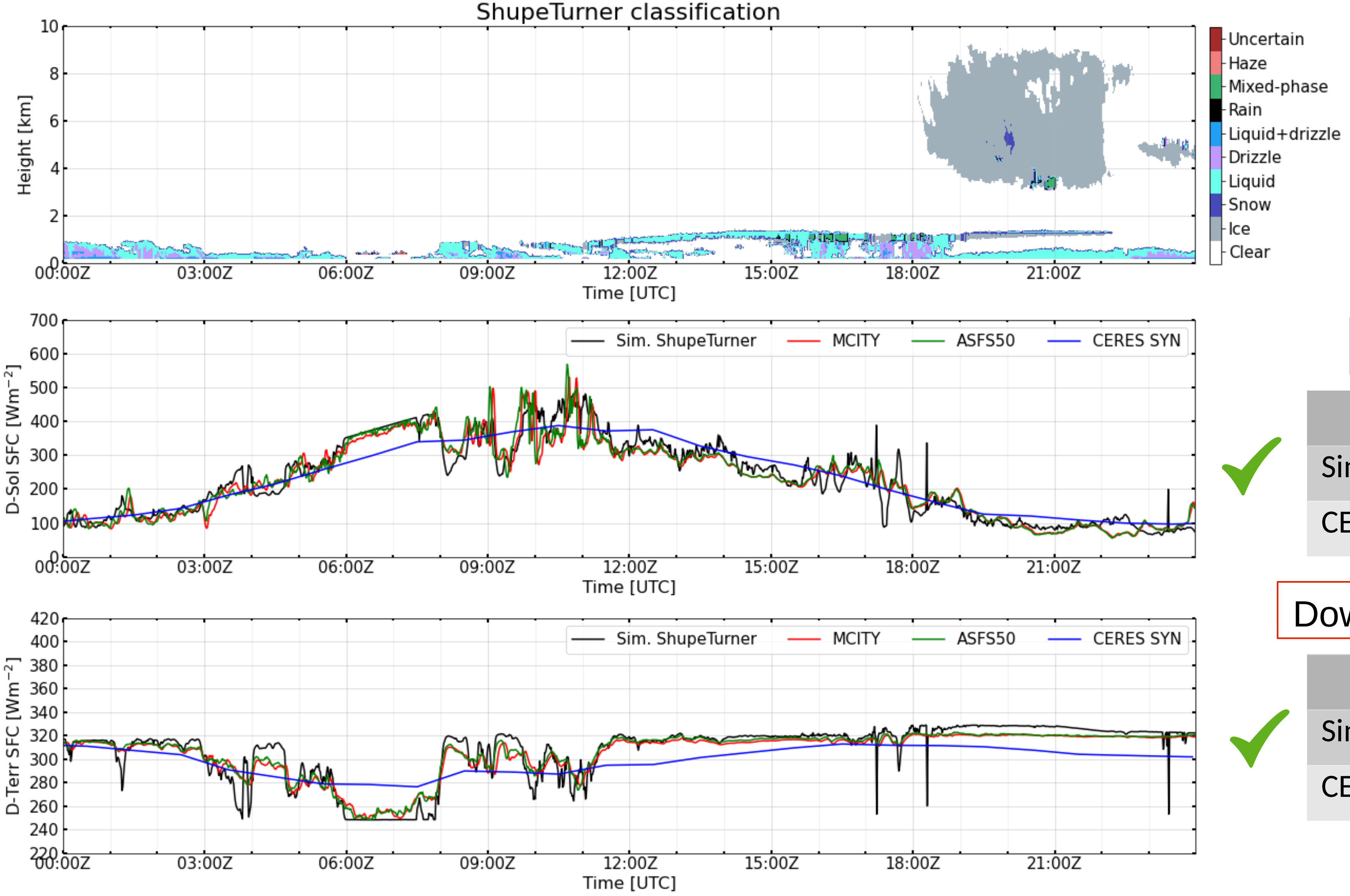
Case study: 2020-07-13

Radiative flux comparison at the BOA

(Simulations - Observations)



Downward Solar flux (D-Sol)

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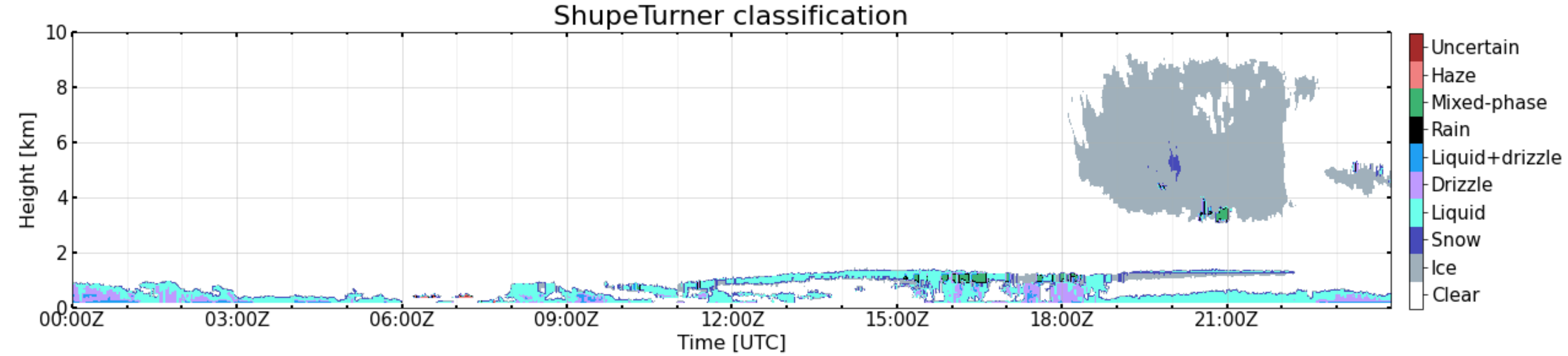
Downward Terrestrial flux (D-Terr)

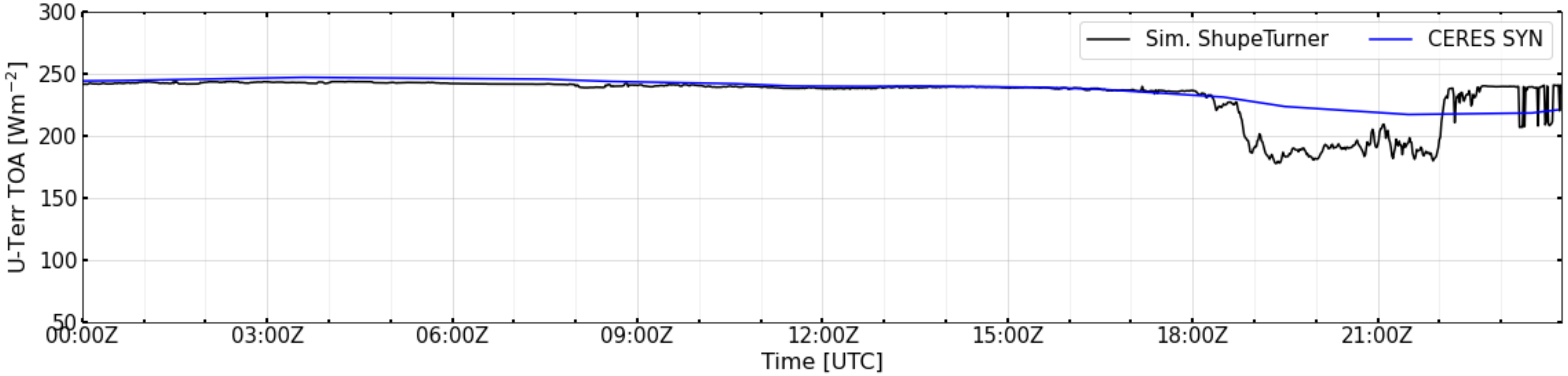
Bias [Wm^{-2}]	MCITY	ASFS50
Sim. ShupeTurner	2.4	1.2
CERES SYN	-6.2	-7.3

Case study: 2020-07-13

Radiative flux comparison at the TOA

(Simulations - Observations)





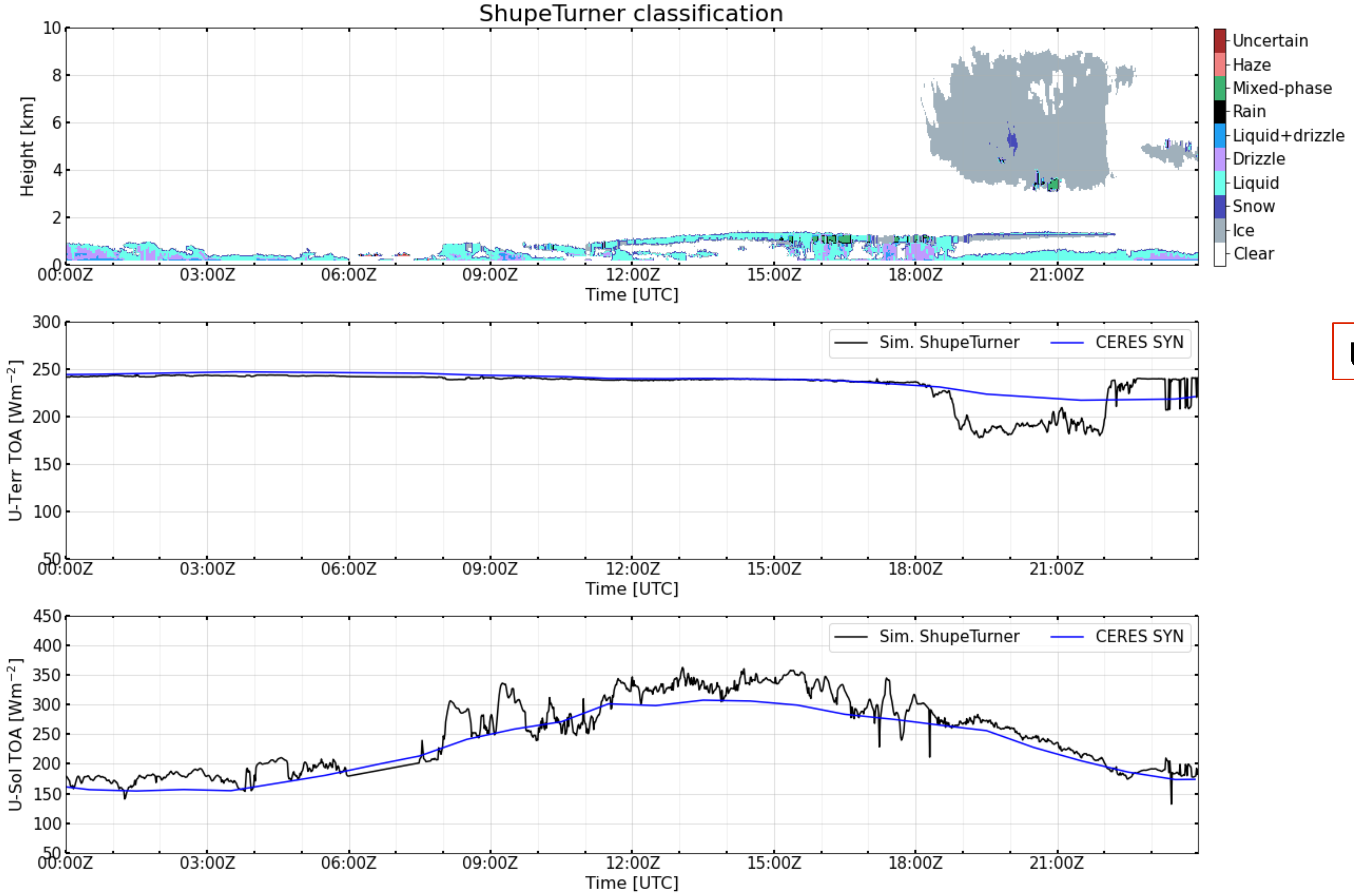
Upward Terrestrial flux (U-Terr)

Bias [Wm^{-2}]	CERES
Sim. ShupeTurner	-4.7

Case study: 2020-07-13

Radiative flux comparison at the TOA

(Simulations - Observations)



Upward Terrestrial flux (U-Terr)

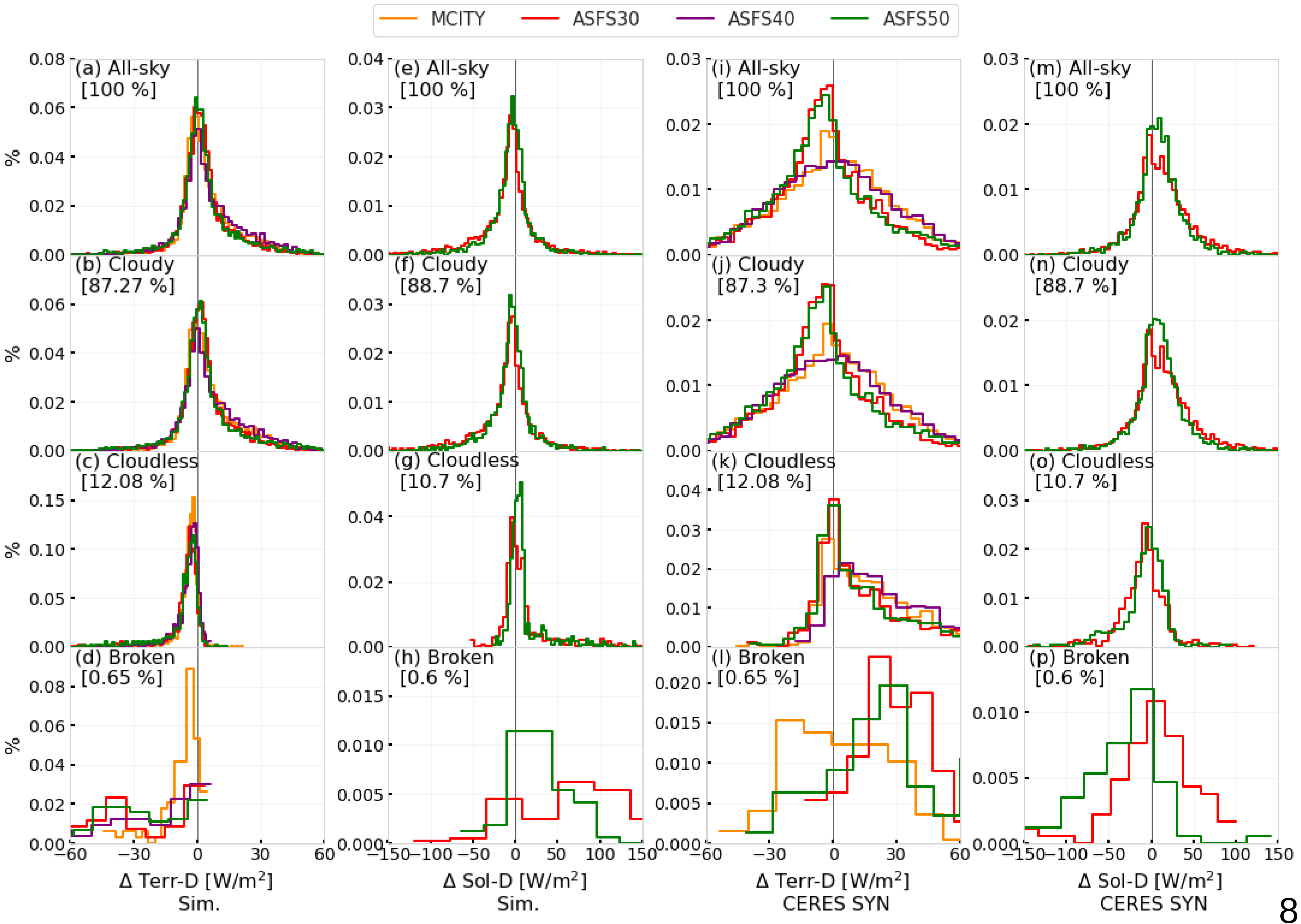
Bias [Wm^{-2}]	CERES
Sim. ShupeTurner	-4.7

Upward Solar flux (U-Sol)

Bias [Wm^{-2}]	CERES
Sim. ShupeTurner	17.2

Radiative flux comparison at the BOA

- Analysis for the entire MOSAiC period to all available stations.
- Overall good agreement for Sim. ShupeTurner simulations and CERES SYN products.
- Discrepancies for CERES SYN products during cloudless conditions attributed to different spatial coverage.

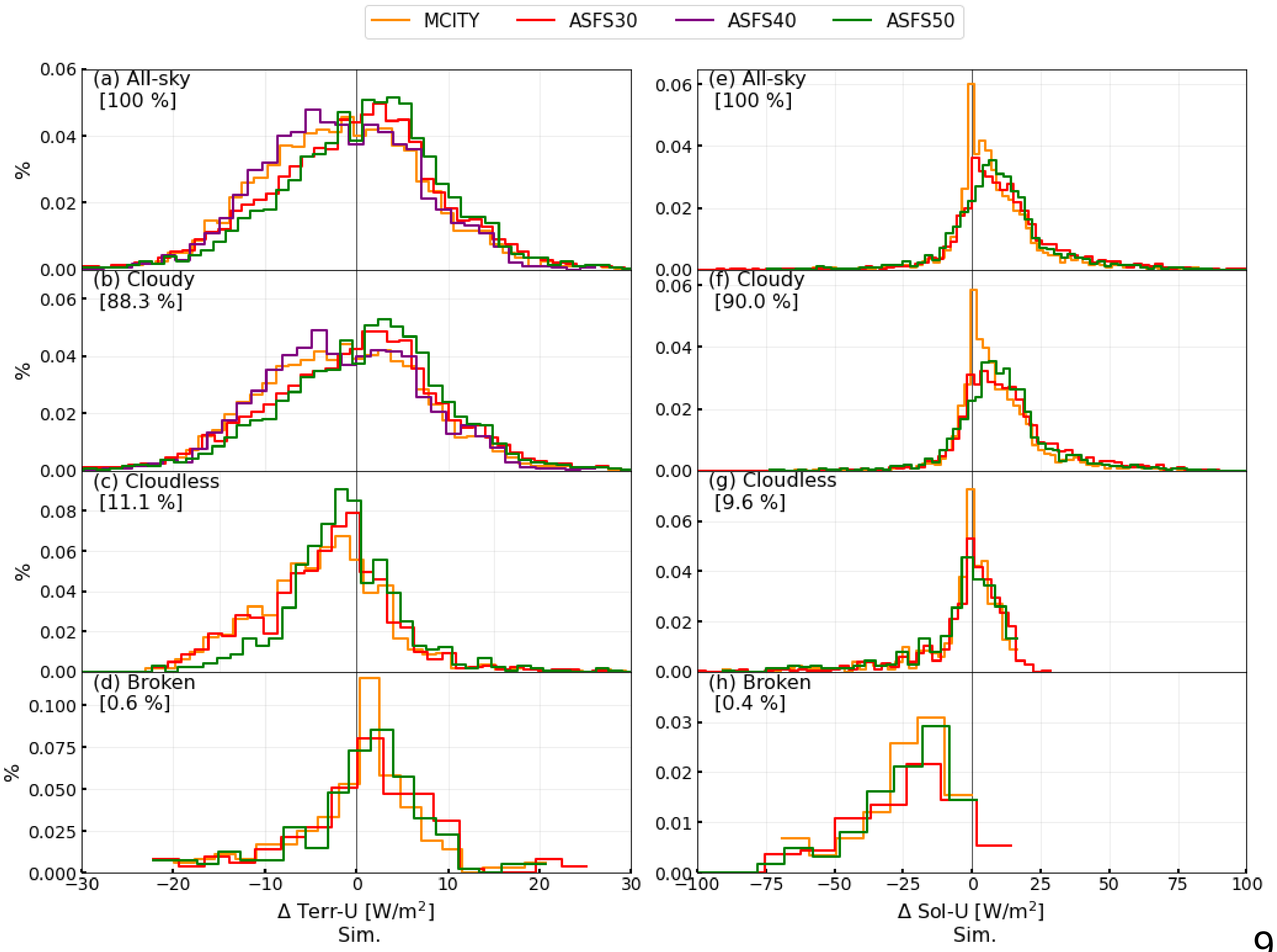


Radiative flux comparison at the TOA

- Sim. ShupeTurner agree well with CERES observations at the TOA.

- Largest discrepancies observed during broken cloud conditions. 1D radiative transfer simulations can't solve such a atmospheric conditions.

- * Additional attention should also be given to simulations under clear-sky conditions.



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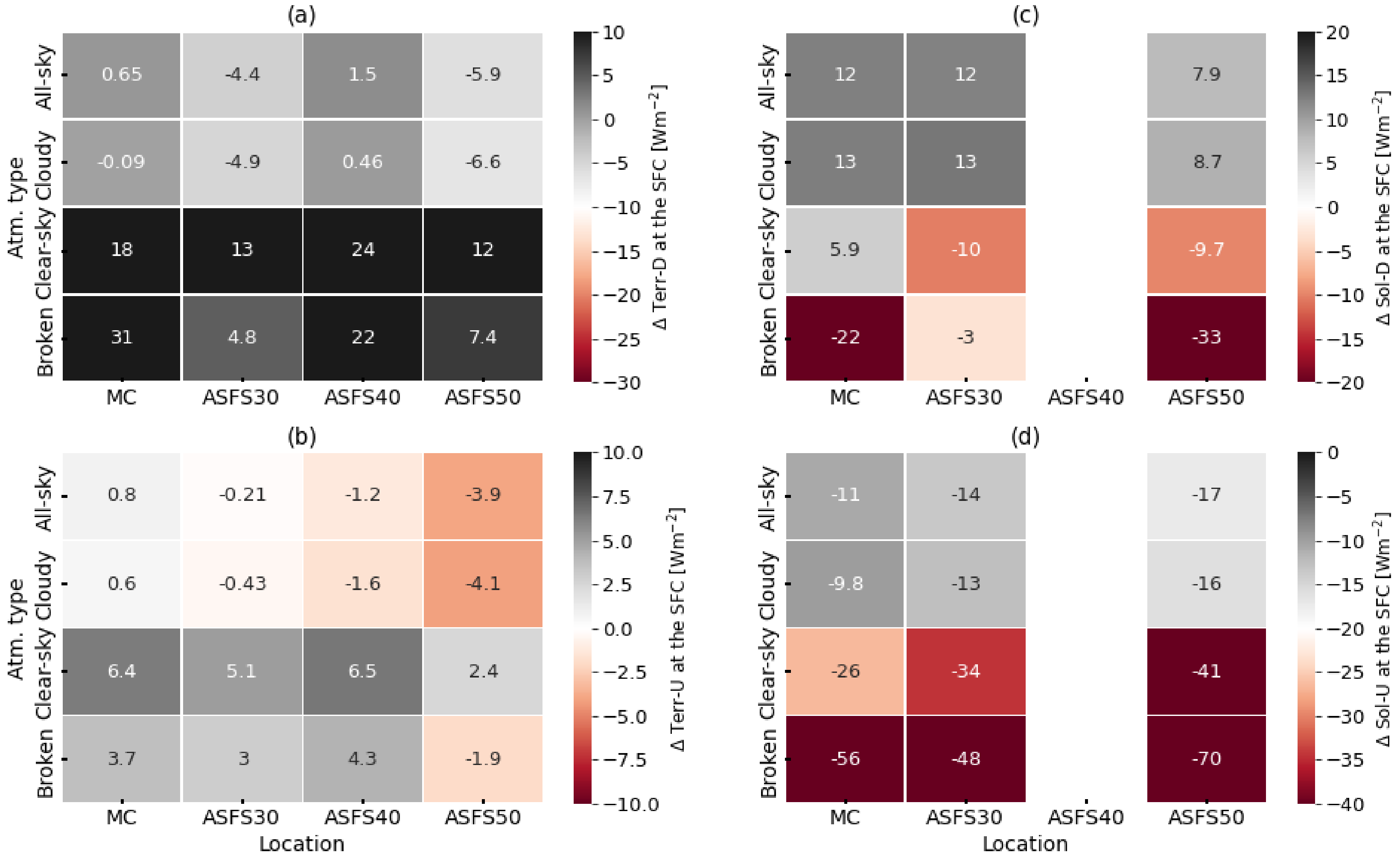
Radiative flux comparison at the BOA

- Overall good agreement for Sim. ShupeTurner simulations and CERES SYN products.
- Most challenging radiative flux comparison is upward solar radiative flux at the TOA.
- Discrepancies for CERES SYN products during Cloudless conditions attributed to different spatial coverage

Mean irradiance difference [Wm^{-2}] for CERES SYN products



Radiative flux comparison at the TOA

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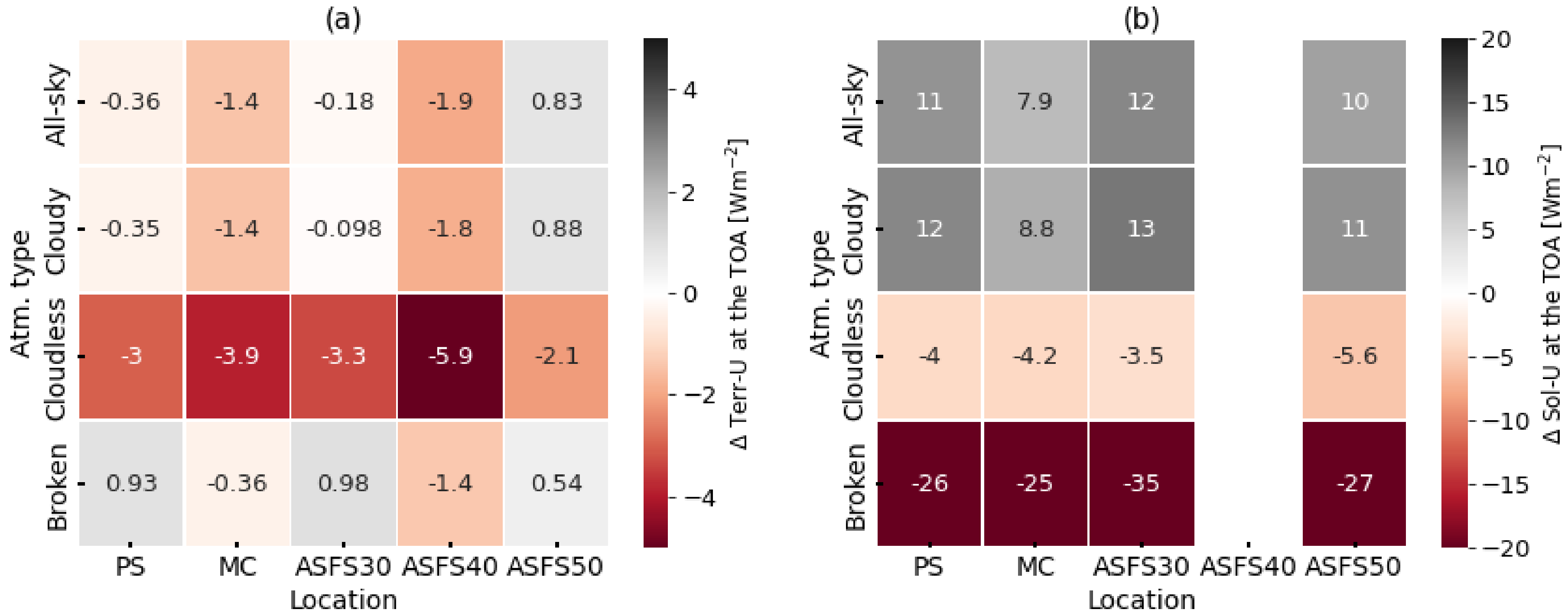
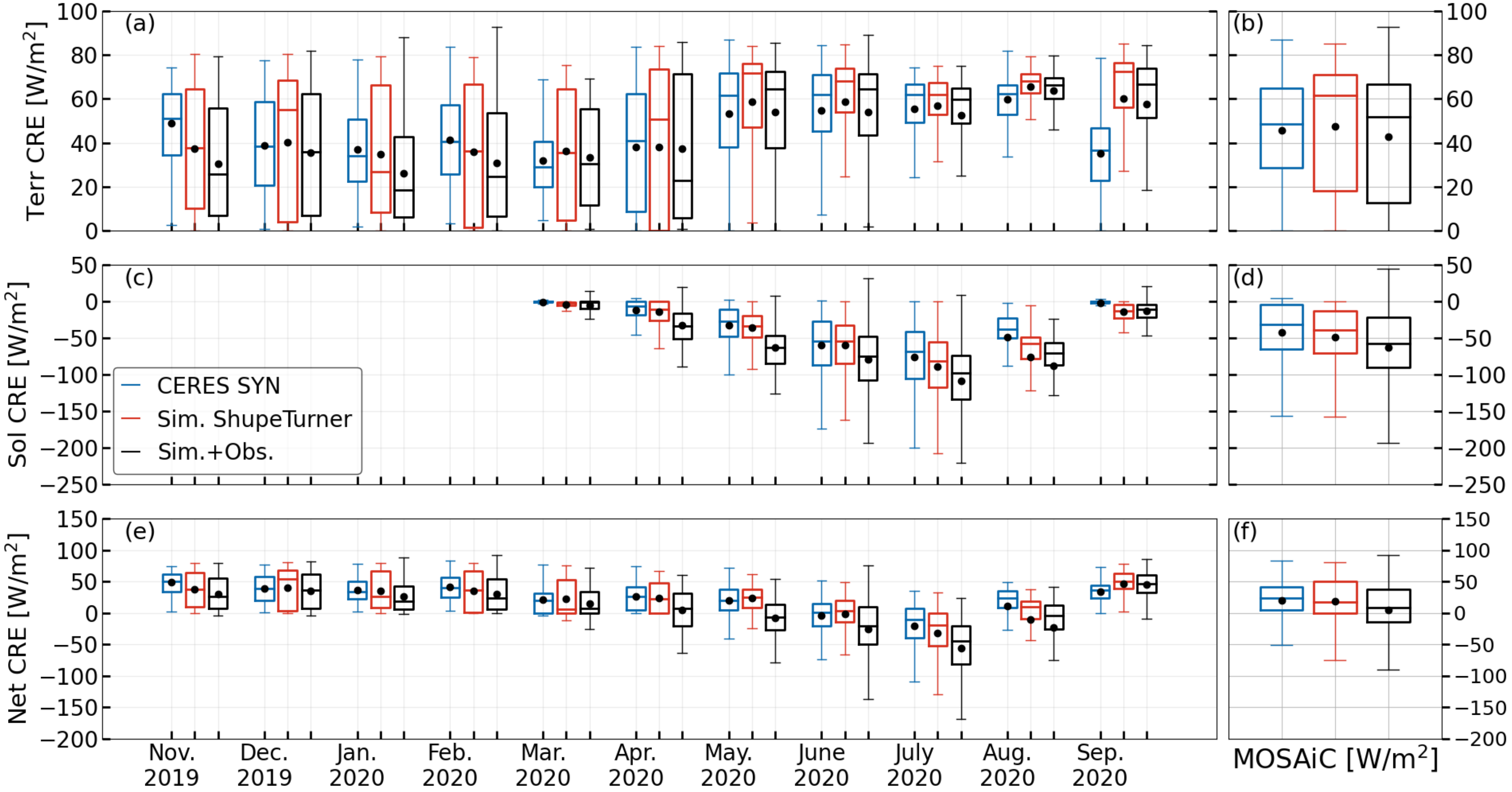
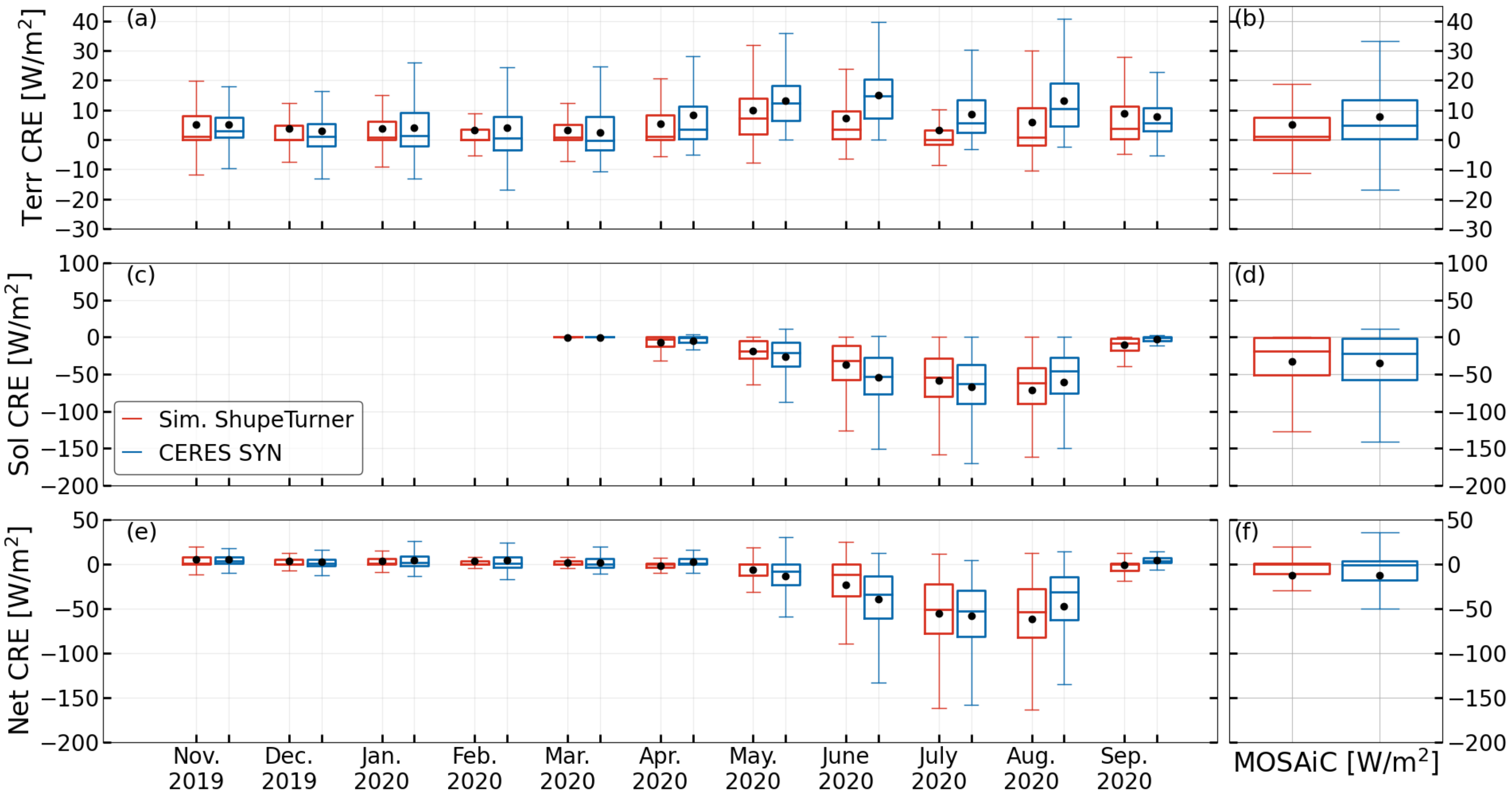


Hourly Cloud Radiative Effect at the BOA



Hourly Cloud Radiative Effect at the TOA



Summary

- Single-column radiative transfer environment TROPOS Cloud and Aerosol Radiative effect Simulator (T-CARS) is an effective tool to calculate profiles of radiative fluxes, and heating rates using the radiative solvers like RRTMG and ecRad.

- T-CARS can help evaluate cloud macro and microphysical retrievals from a synergistic combination of active and passive remote sensing observations (e.g., ShupeTurner, Cloudnet, ARM retrievals).

- Current study focuses on the MOSAiC expedition. However, its applicability can go beyond the Arctic region→ EarthCARE CAL/VAL analysis, several campaigns e.g., CleanCloud, CERTAINTY, etc.).

- Several ground-based radiometers are recommended to better understand radiative differences due to different spatial coverage and further investigate 3D effects.

Thank you for your attention

Questions?

Bundesministerium für Bildung und Forschung

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