Quantifying 3D radiative transfer effects of clouds using ML-generated 3D cloud scenes for EarthCARE, and airborne observations from ORCESTRA/PERCUSION campaign

EarthCARE 2026 Science and Validation workshop

8–12 June 2026 | Rhodes House | Oxford, UK

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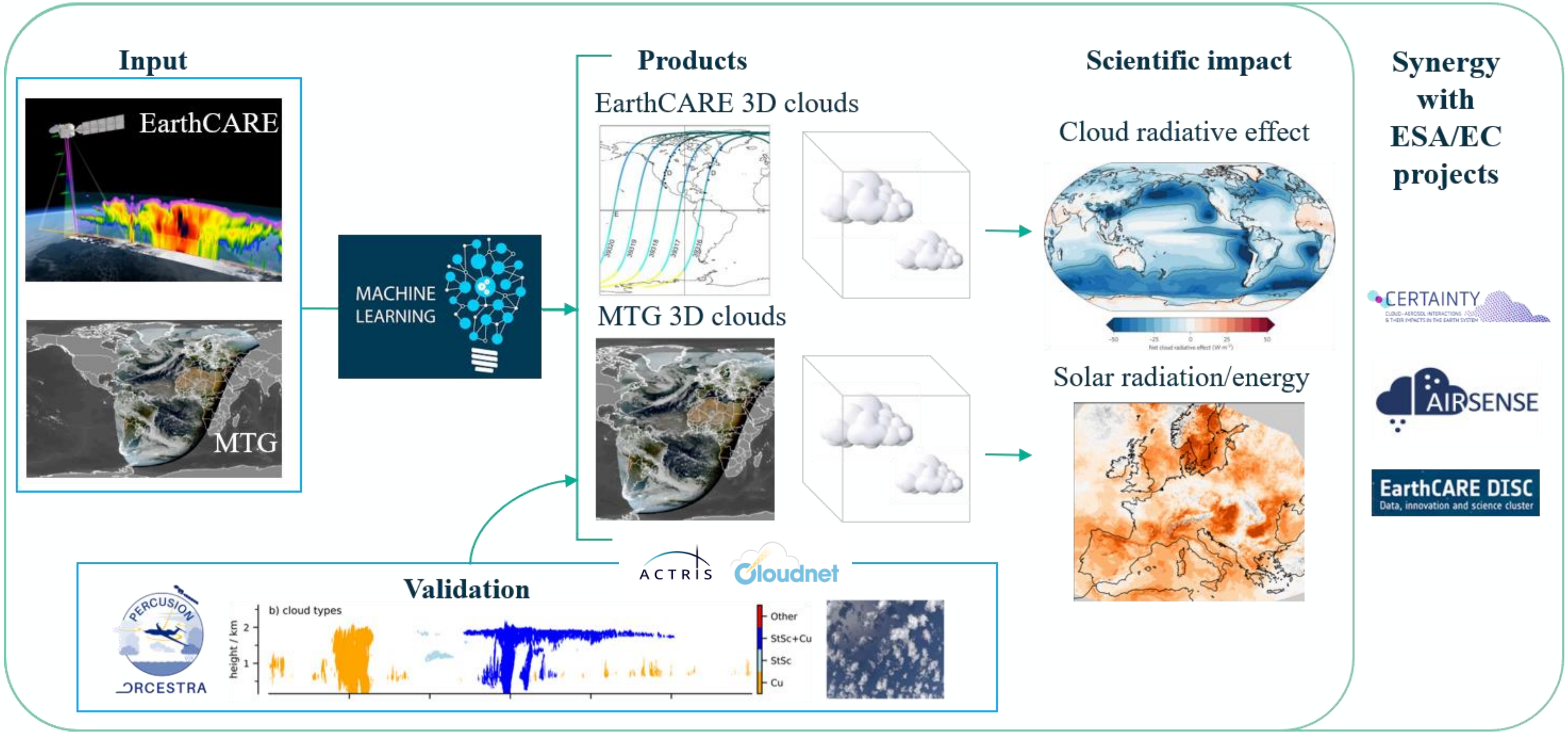
3D Cloud Microphysical Products Using EarthCARE, MTG and AI



Obs3RvE

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

pmod wrc

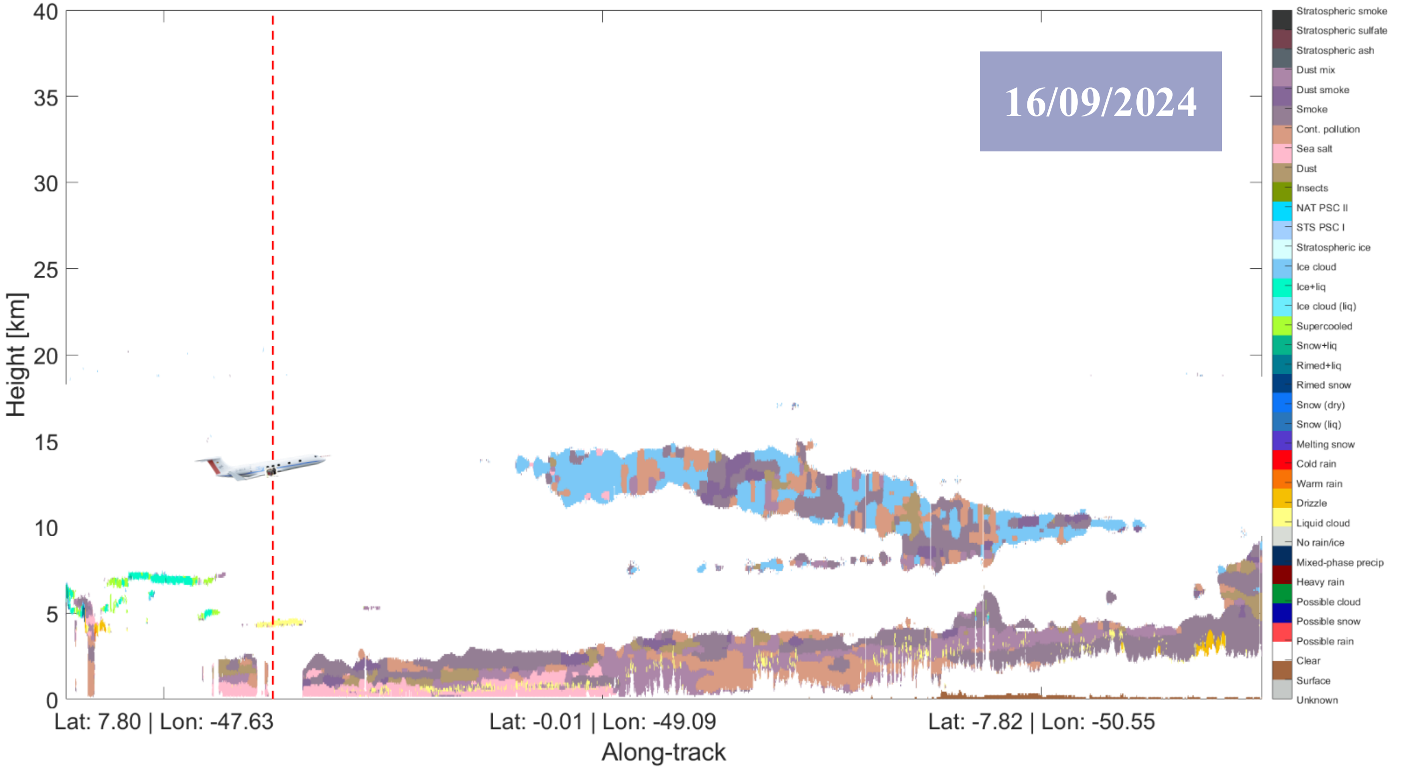
esa

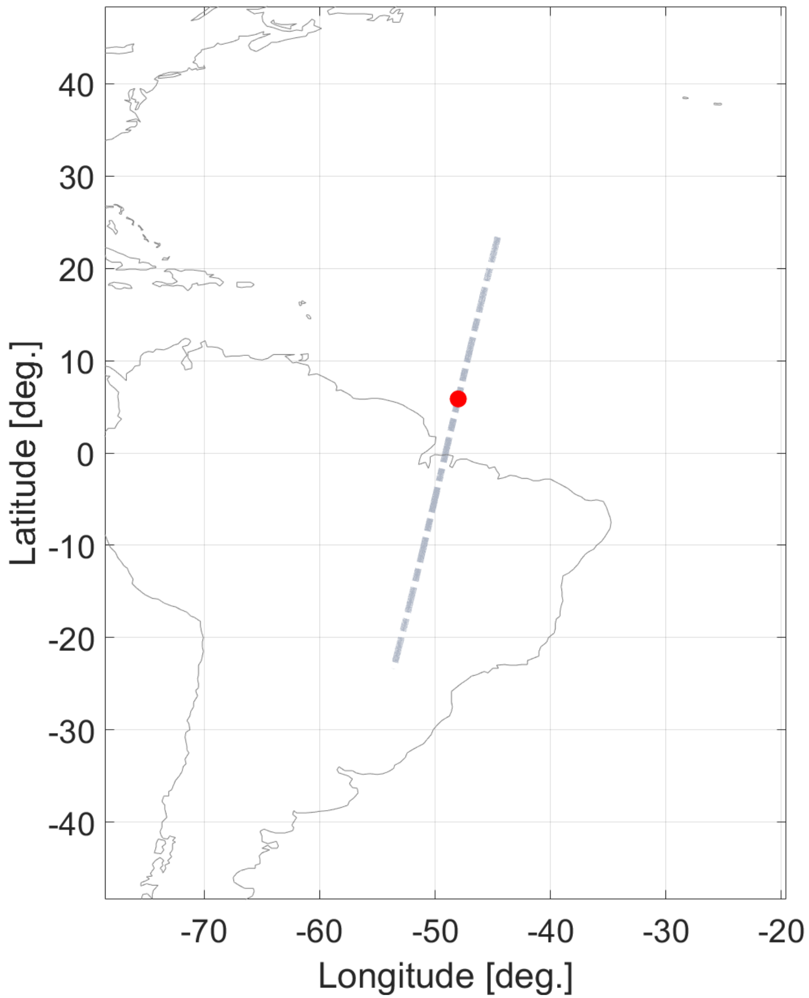
Website: *https://climatehub.gr/react/Obs3RvE*

Why we need 3D RT for clouds?

Radiative Closures during ORCESTRA/PERCUSION with BBR effective fluxes at TOA under cloud-sky conditions.

AC-TC Target Classification (BA Baseline)





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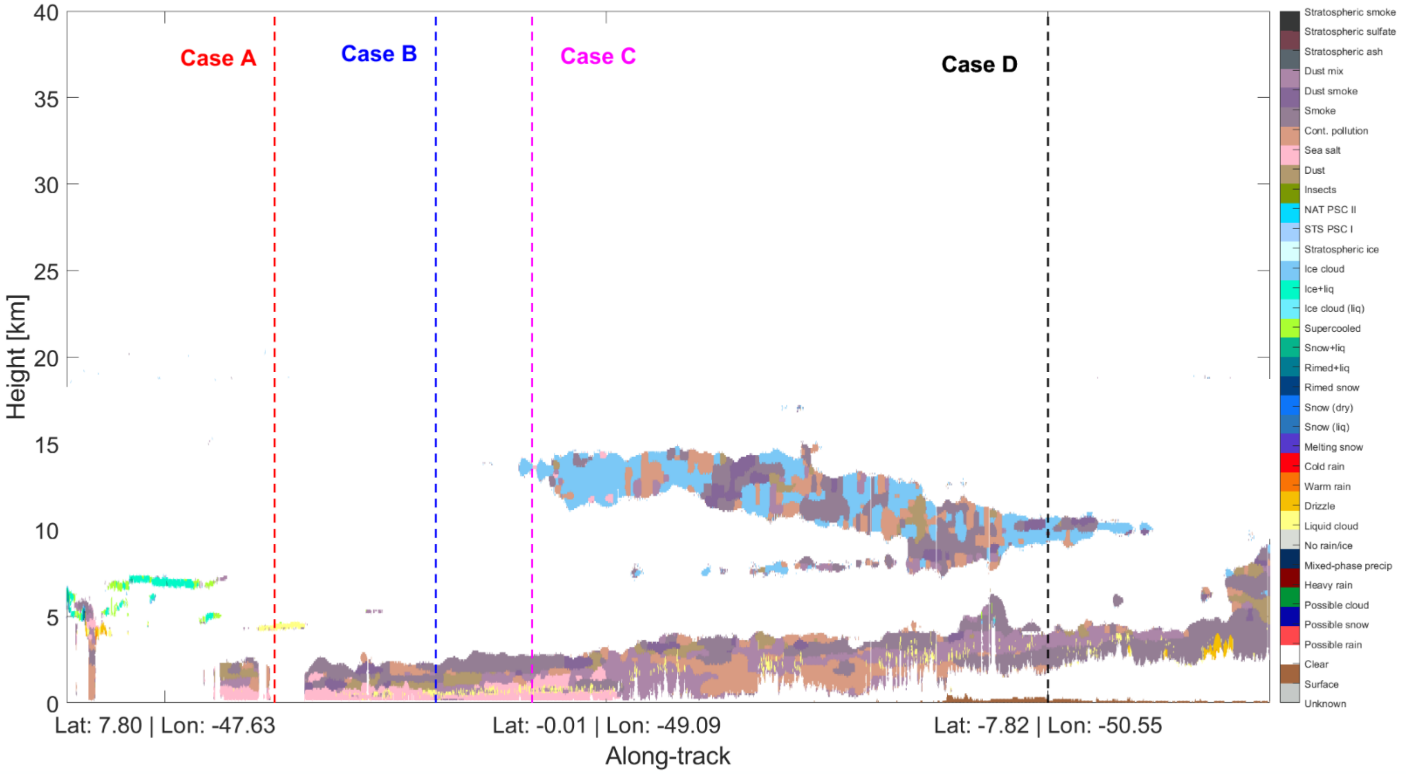

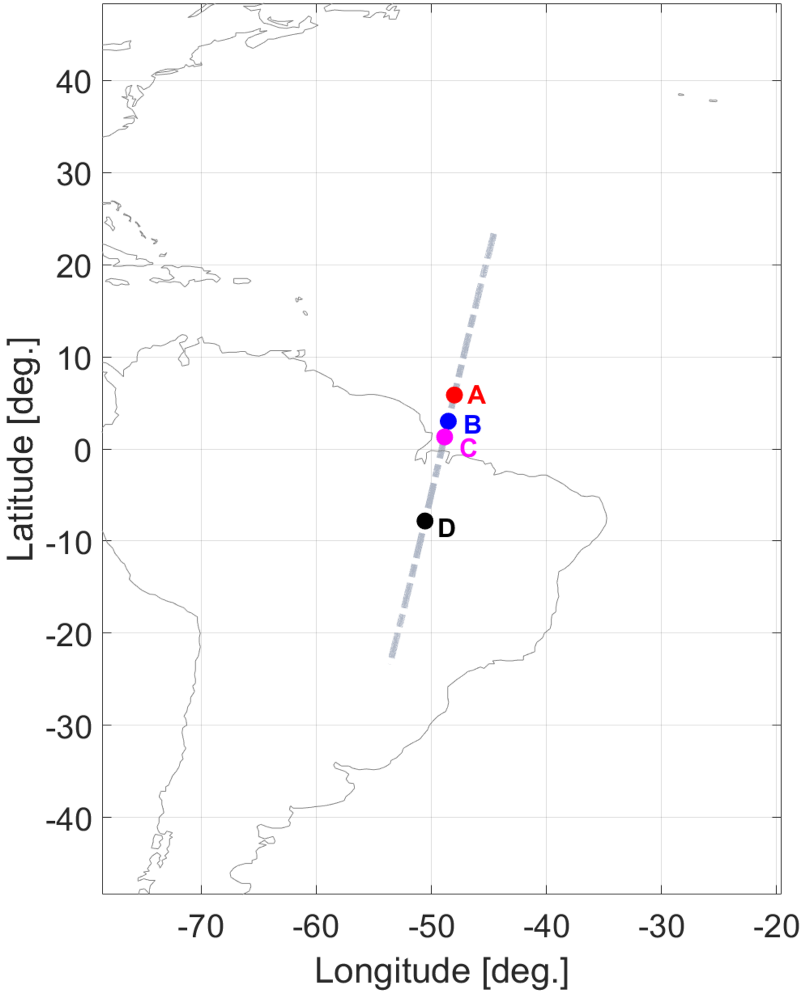

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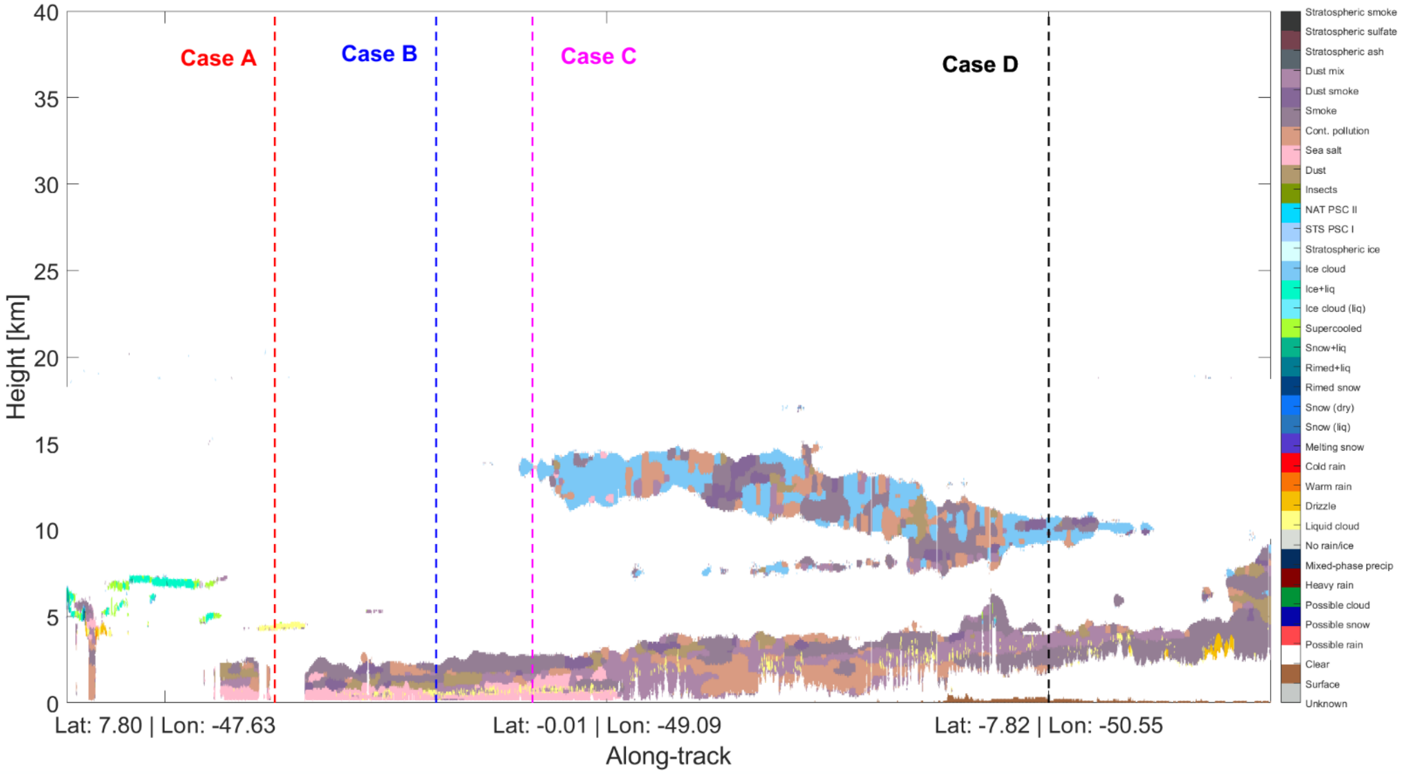

For **4 selected cases** along the same orbit on 16/09/2024:

- **EarthCARE L2 products** (ACM-COM, ACM-CAP, ALL-3D, BMA-FLX)
- **1D and 3D Radiative transfer model** (libRadtran/MYSTIC)

⇨ **Comparison with shortwave fluxes and radiances** from the EarthCare L2 products (BM-RAD, BMA-FLX)

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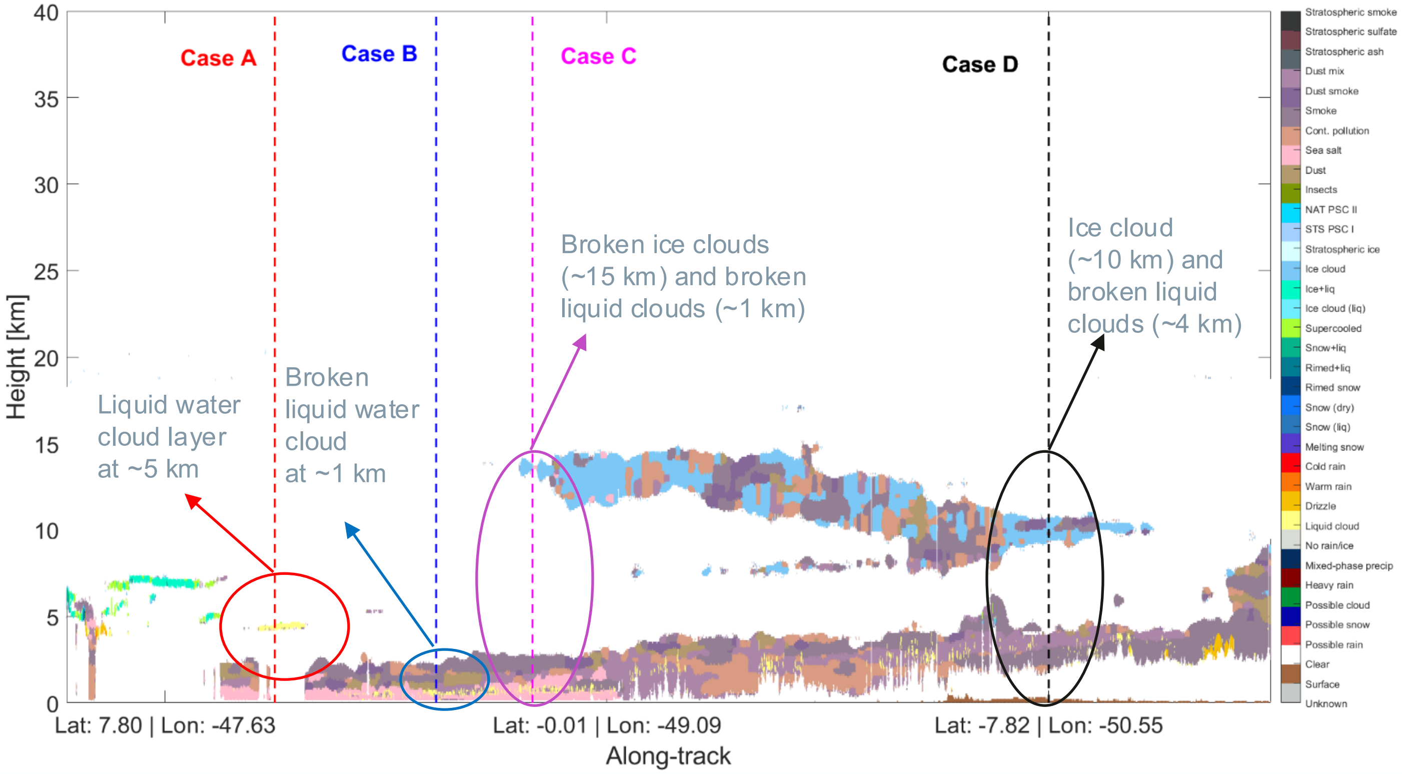

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libRadtran
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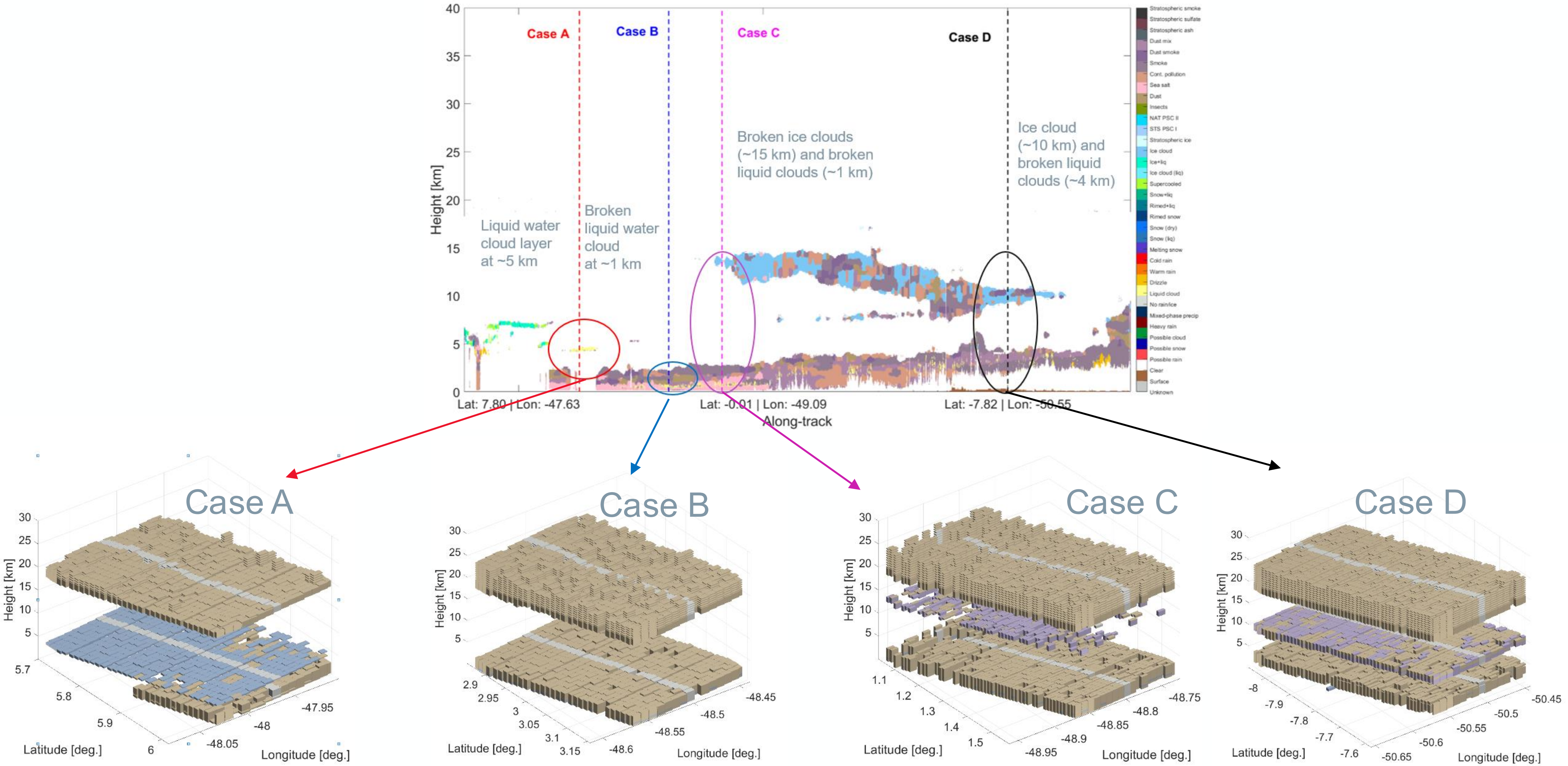
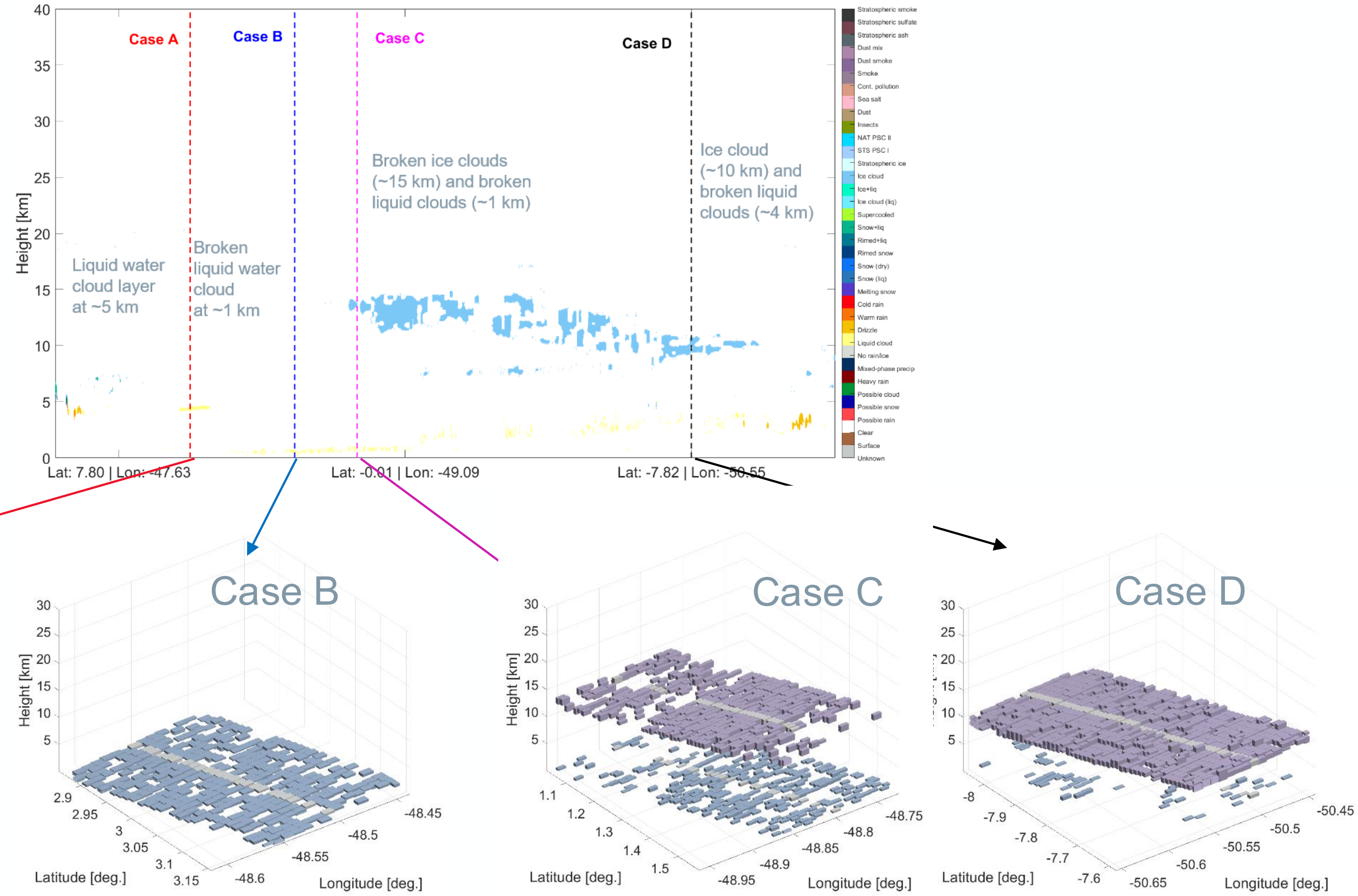
3D EarthCARE scenes



3D EarthCARE cloud scenes

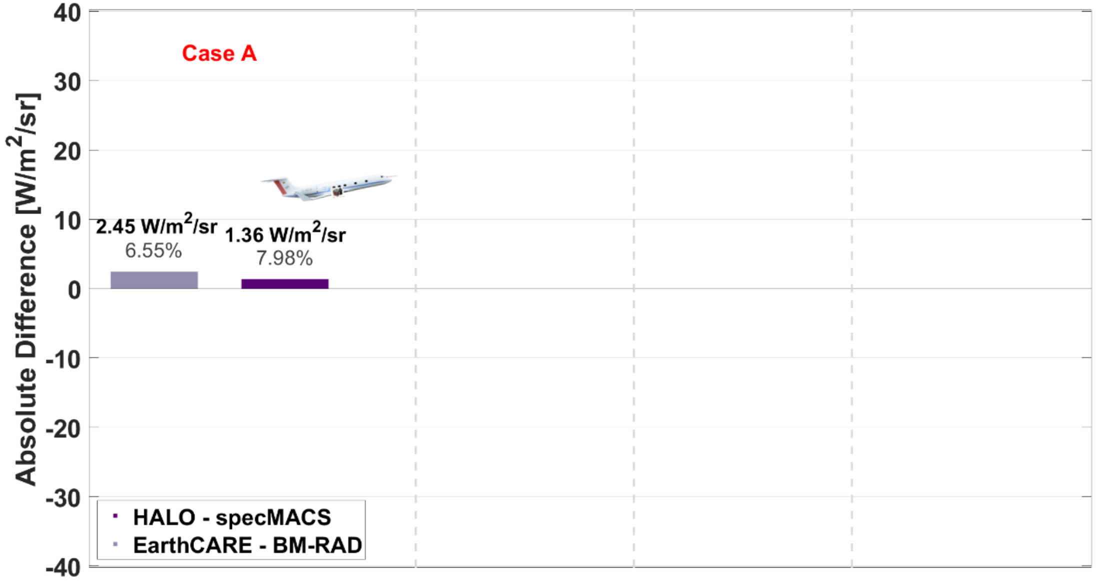


3D vs 1D RT Closures

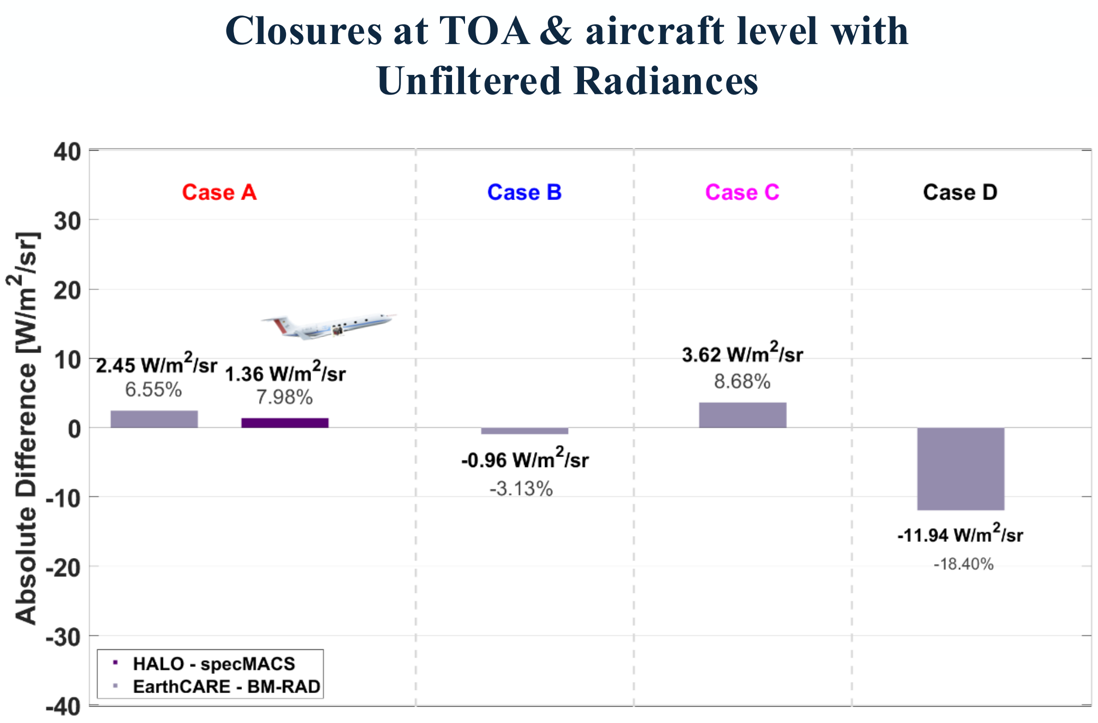
RT Closures at the top of the atmosphere (TOA) and at aircraft level

3D Results

Closures at TOA & aircraft level with Unfiltered Radiances



3D Results



Closures at TOA & aircraft level with
Unfiltered Radiances
Absolute Difference [W/m²/sr]
40
30
20
10
0
-10
-20
-30
-40
Case A
Case B
Case C
Case D
2.45 W/m²/sr
6.55%
1.36 W/m²/sr
7.98%
-0.96 W/m²/sr
-3.13%
3.62 W/m²/sr
8.68%
-11.94 W/m²/sr
-18.40%
HALO - specMACS
EarthCARE - BM-RAD

3D Results

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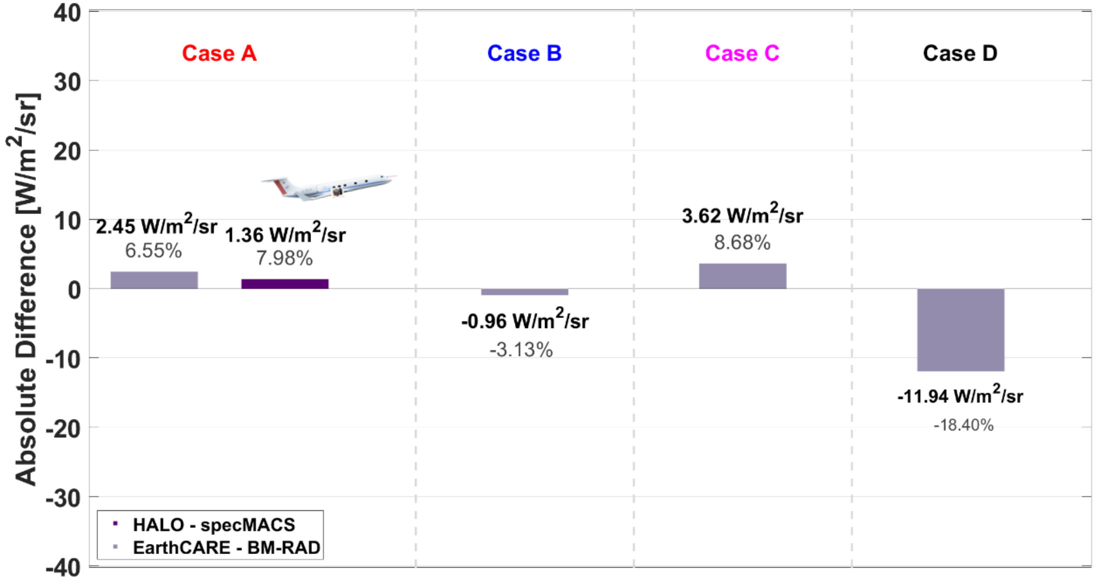
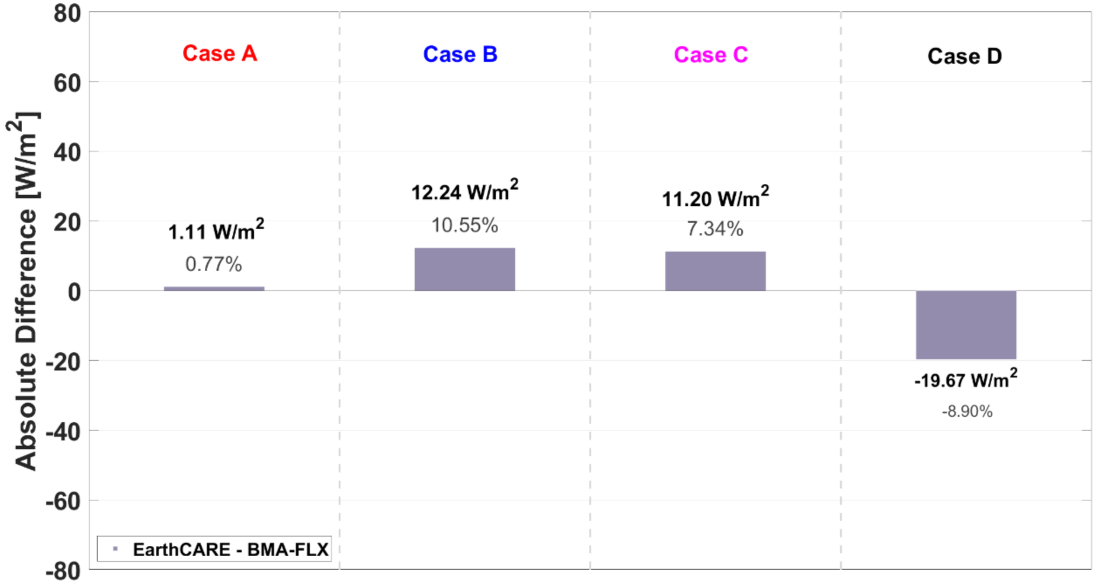
Closures at TOA & aircraft level with Unfiltered Radiances

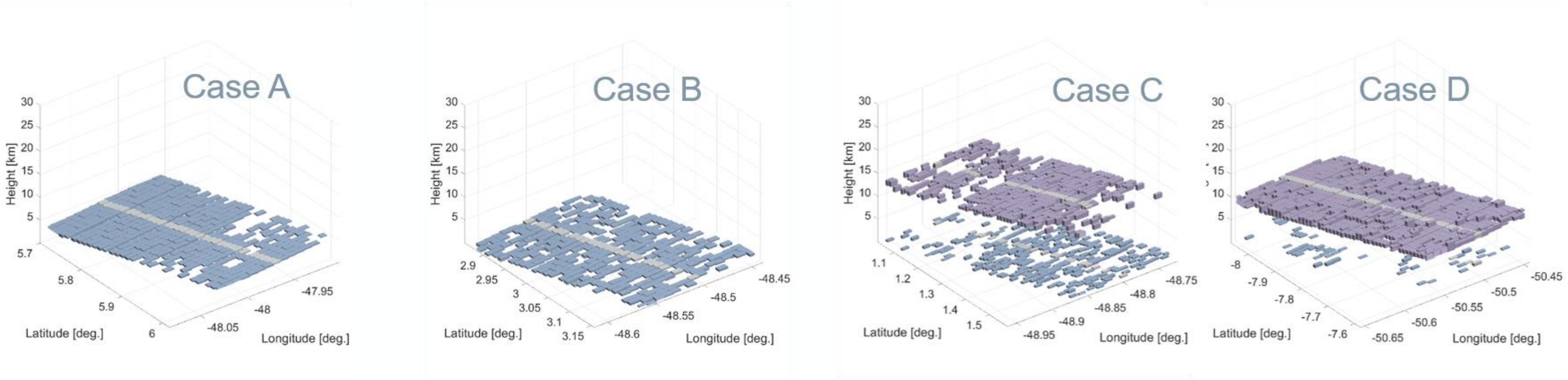


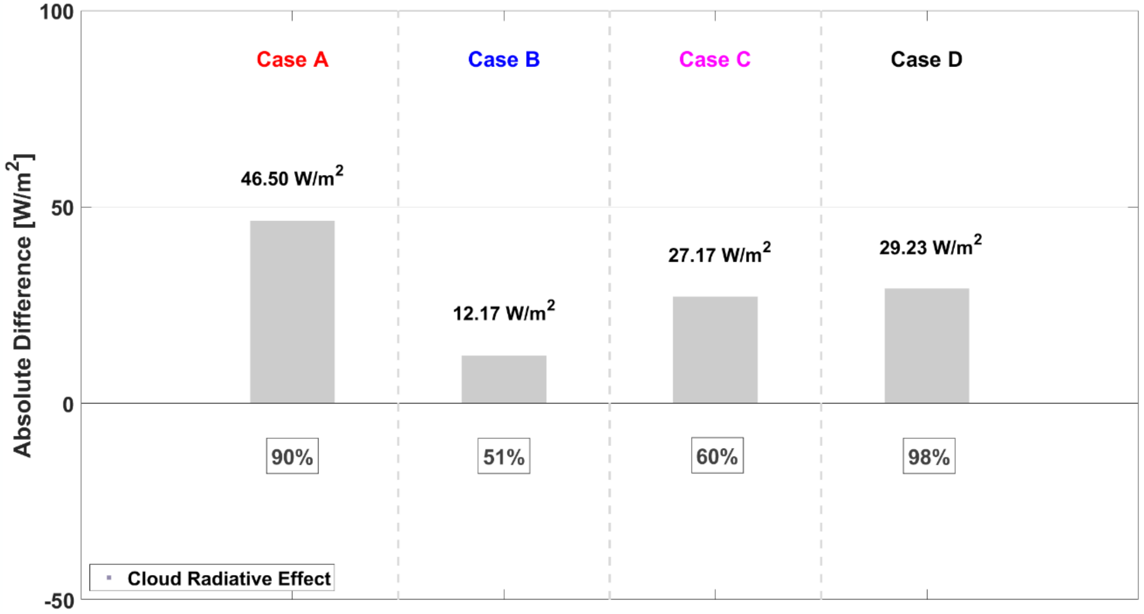
Closures at TOA with Effective Fluxes



Overall **good agreement for both radiances and fluxes** (close to ±10 W m⁻² mission target) with higher deviation in **Case D**

Cloud Radiative Effect - 3D RT

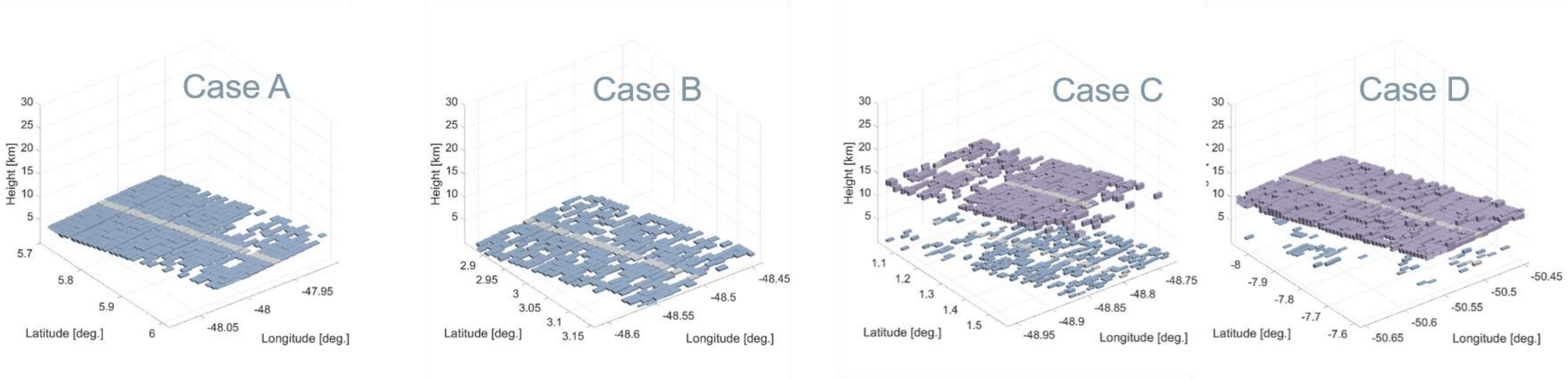


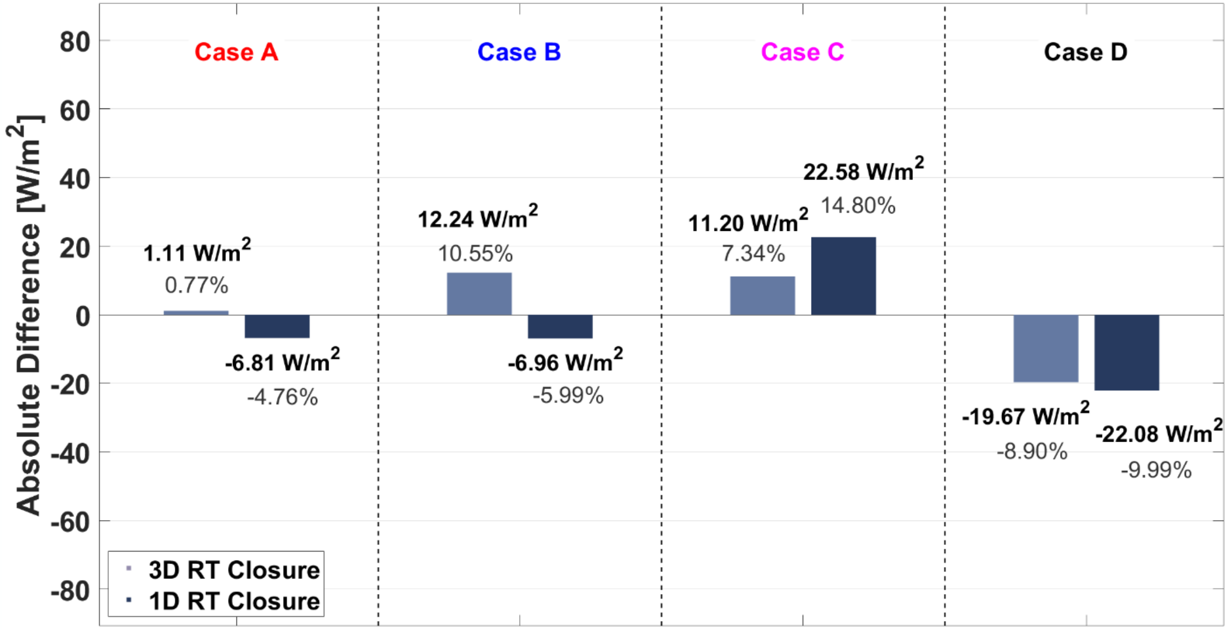


Higher cloud coverage → Higher CRE
High water content → Increased CRE

Cloud Radiative Effect (CRE) *= all-sky fluxes – cloud-free sky at TOA*

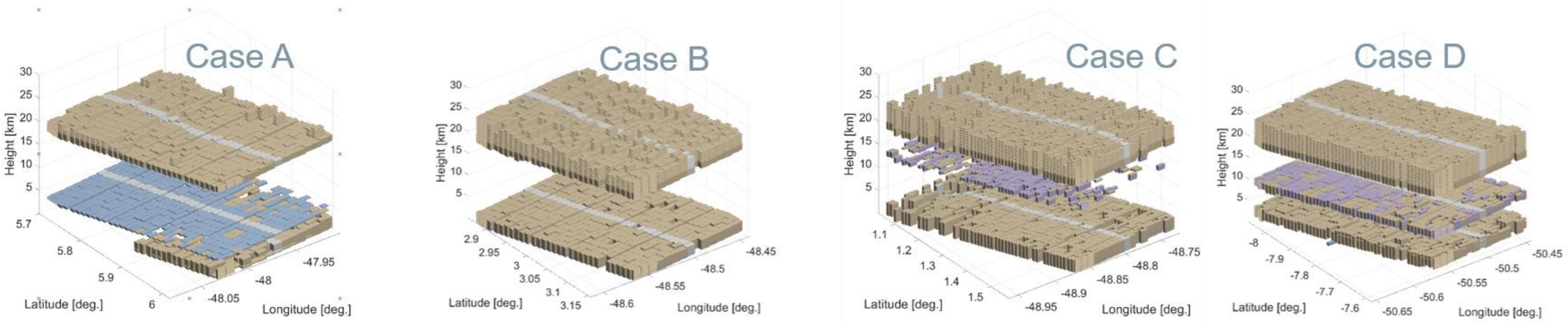
3D and 1D Comparison

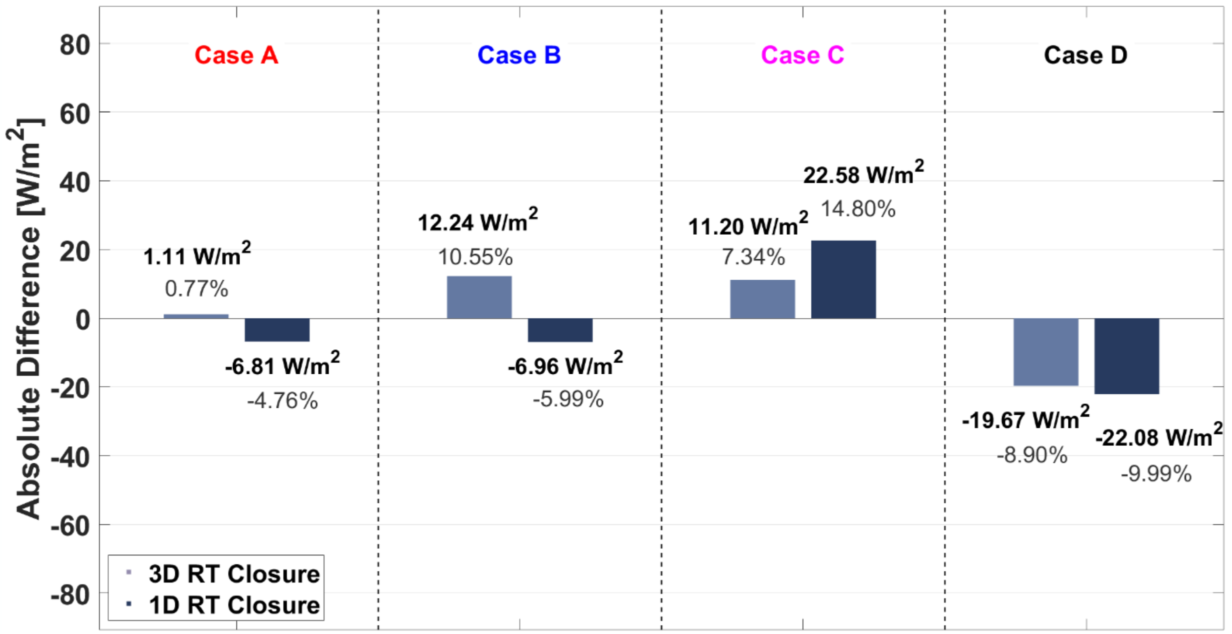




Overall, **better agreement** between **3D RT** simulations and observations

3D and 1D Comparison





Overall, **better agreement** between **3D RT** simulations and observations

Comparison between BC & BD Baselines

ACM-CAP BC & BD RT Closures

Comparison of ACM-CAP Baselines BC, BD in Radiative Closures - Fluxes

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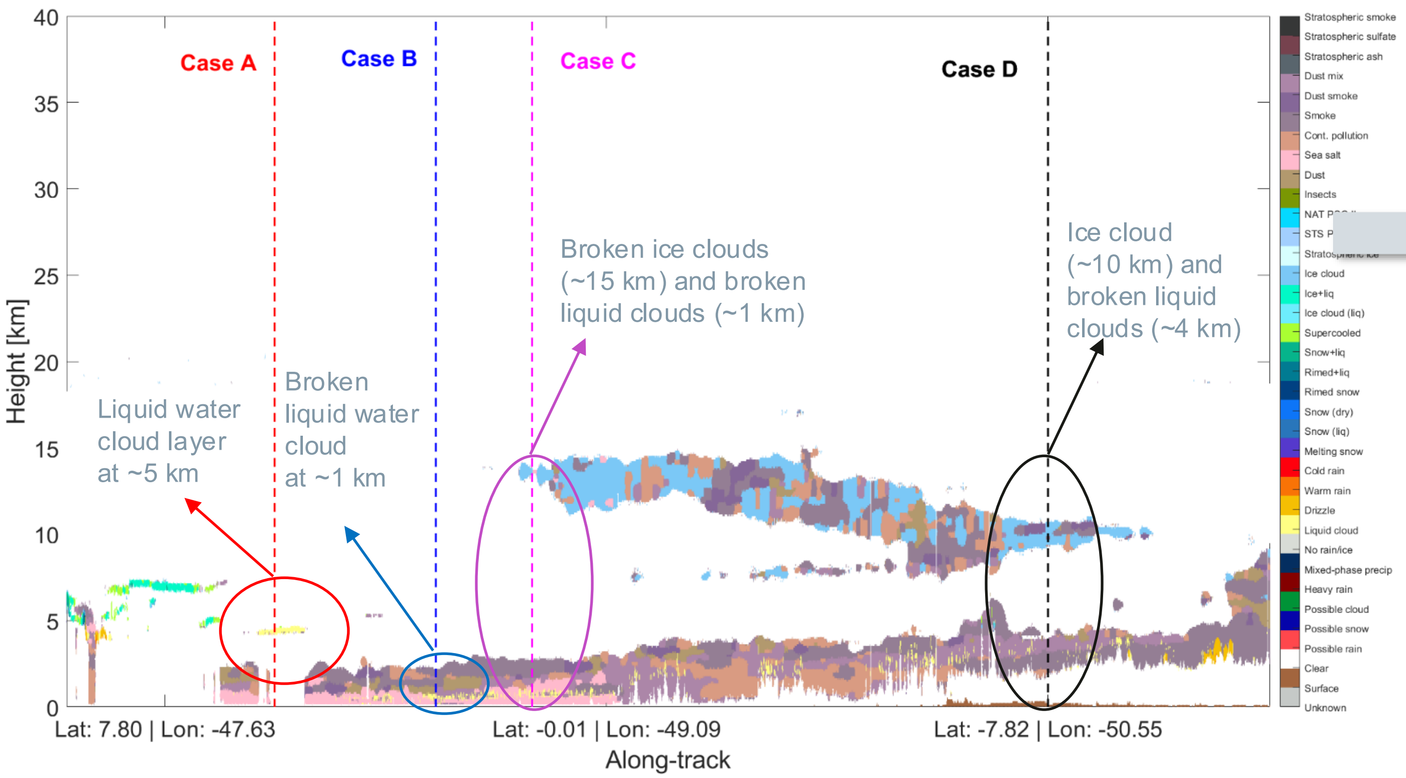
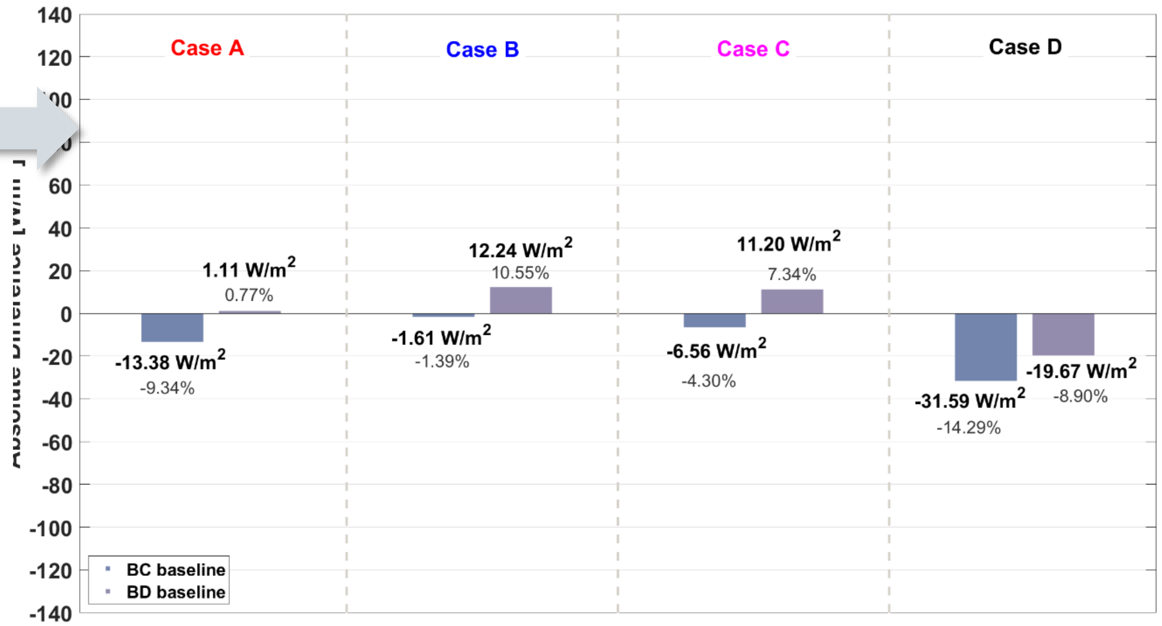
Radiative Closures during ORCESTRA/PERCUSION with BBR Effective Fluxes at TOA under cloud-sky conditions.

PERCUSION ORCESTRA

AC-TC Target Classification (BA Baseline)



EarthCARE L2b ACM-CAP product
Comparison between Baselines BC and BD

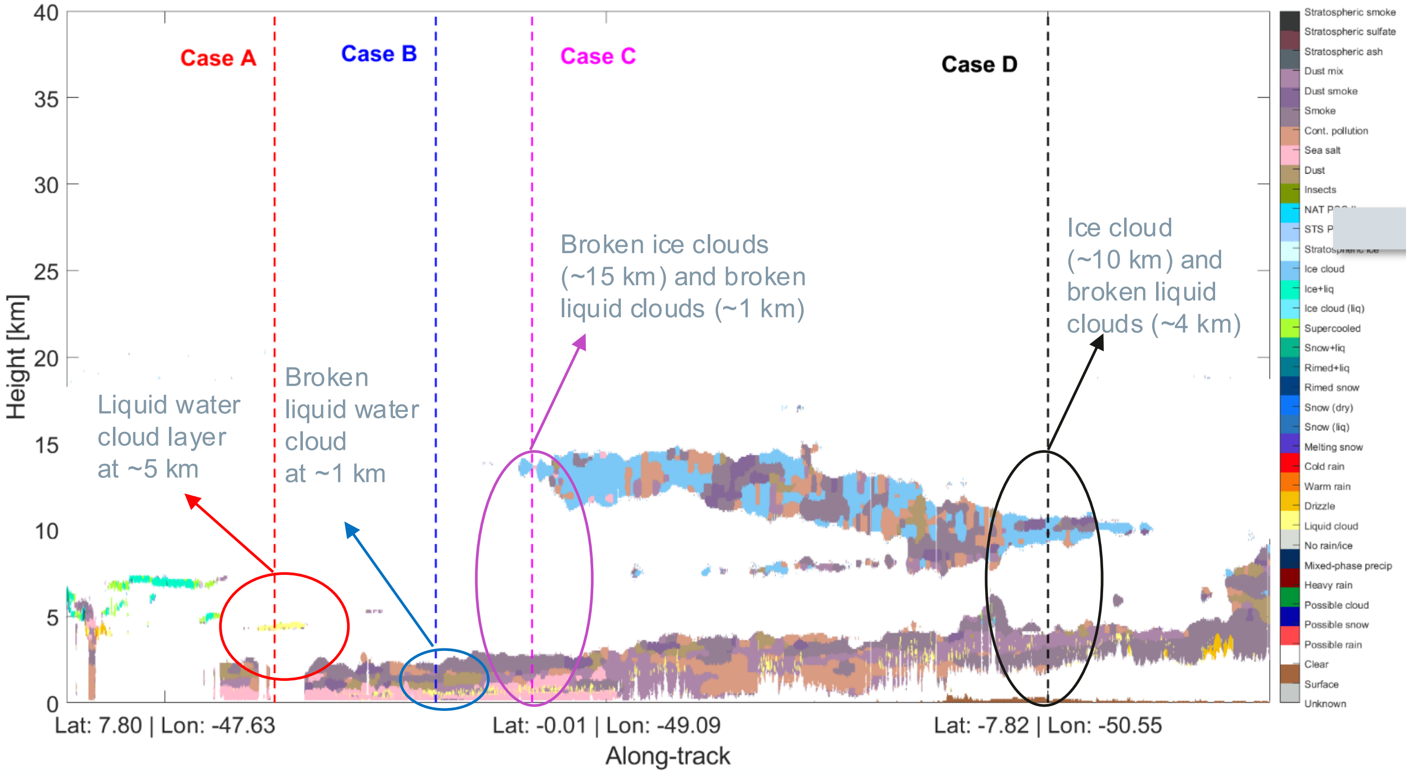


- Overall **good agreement** (close to ±10 W m⁻² mission target)
- Larger deviations for **both baselines in Case D**
- **No systematic difference** between BC and BD
- **BD** generally led to **higher TOA fluxes** than BC

Comparison of ACM-CAP Baselines BC, BD in Radiative Closures - Radiances

Radiative Closures during ORCESTRA/PERCUSION with BBR Unfiltered Radiances at TOA under cloud-sky conditions.

AC-TC Target Classification (BA Baseline)



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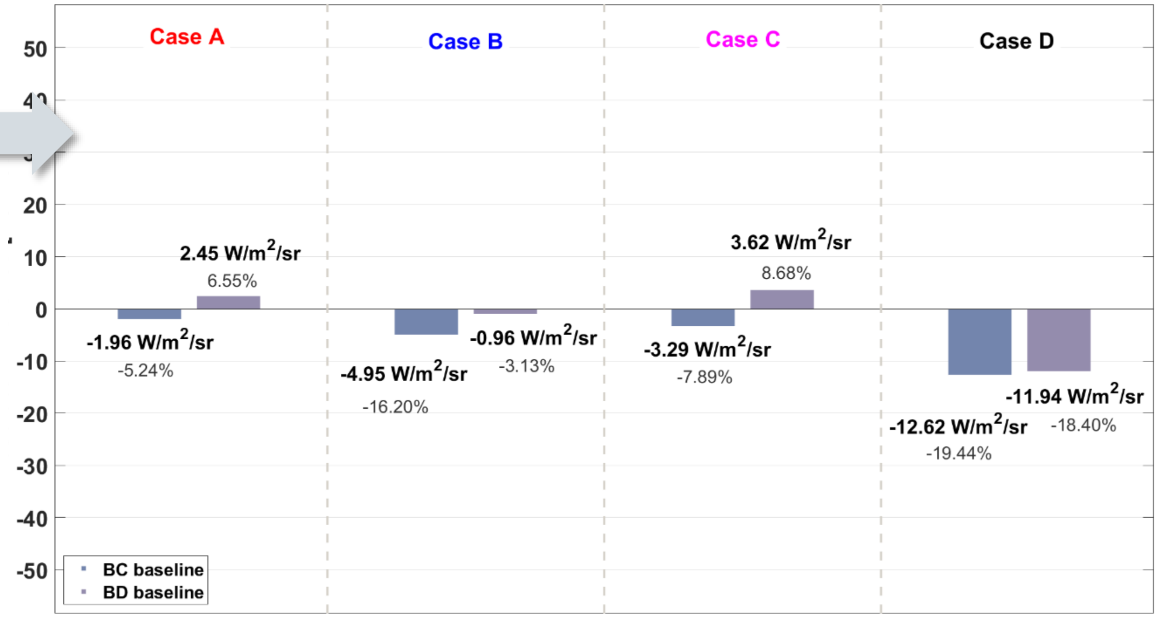


- Overall, **good agreement** with both baselines
- **BD** also led to **higher TOA radiances** than BC
- **No systematic difference** between BC and BD
- Larger deviations for both baselines in Case D, also for radiances

New 3D cloud product from EarthCARE, MTG and AI

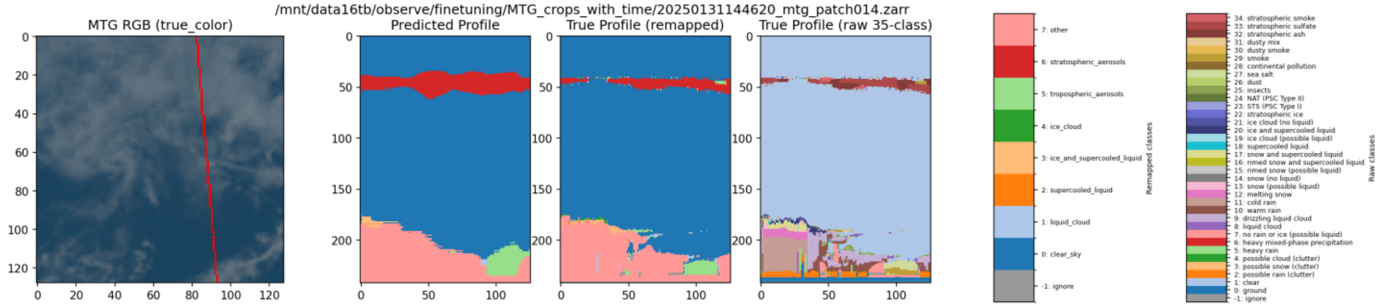
Machine Learning-based new 3D cloud product for Radiative Transfer simulations

Obs3RvE

Machine Learning Retrieval

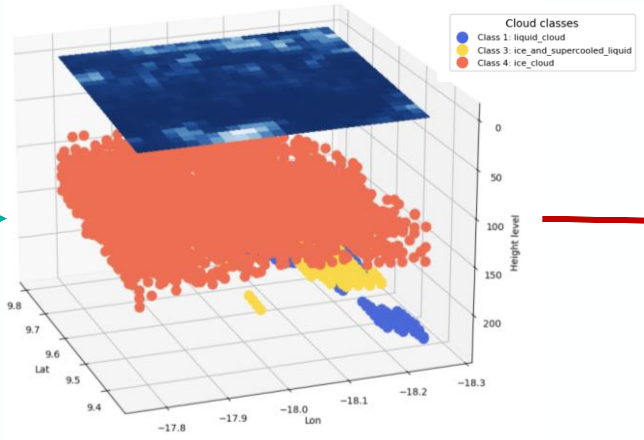
Machine Learning Retrieval of Near-Real-Time 3D EarthCARE Scenes from MTG-FCI Observations

Girtsou et al. T130, Session: Novel Developments - Clouds and Convection



2D cloud-type predicted profiles

3D cloud-type predicted domains



3D cloud-microphysical properties predicted domains

3D RT calculations

libRadtran
MYSTIC

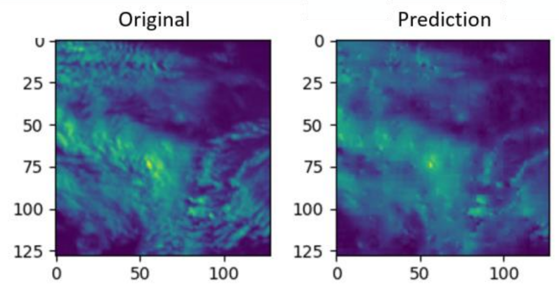
Estimation of CRE and top-of-the-atmosphere (TOA) closure with BBR Observations

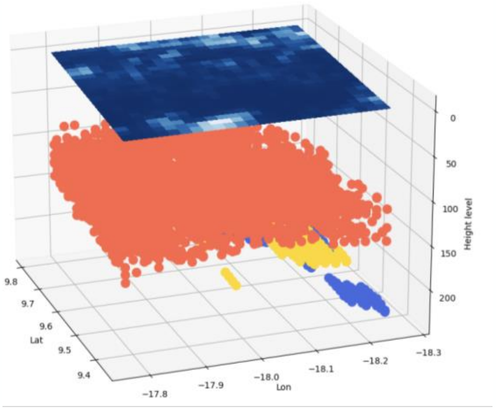
Conclusions

- Overall **good agreement for both radiances and fluxes** (close to ±10 W m⁻² mission target)
- Larger deviations were revealed only in one case (Case D) – the only case over land
- **CRE** increased with cloud coverage scenes and water content
- Comparison between **3D** and **1D** RT closures revealed a **better agreement** between **3D RT** simulations and observations in most cases
- The implementation of ACM-CAP Baselines (BC and BD) led to **higher TOA radiances and fluxes in the case of BD**

Future Steps

Science goal: improving the quantification of cloud radiative effect





- 3D cloud-microphysical properties predicted domains for cloud radiative effects and RT closures at TOA

- Comparison of radiative closures at TOA with ACMB-DF EarthCARE product

This research was funded by the Copernicus Climate Change Service (C3S), under contract C3S2_461-1_GR_NOA. C3S is one of six services of the Copernicus Earth Observation Programme and is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) with funding from the European Commission, the Obs3RvE (Optimising 3D RT Earthcare product using geostationary observations and AI) project, funded from the European Space Agency under Contract No. 4000147848/25/I/AG, the COST Action < HARMONIA, CA21119>, supported by COST (European Cooperation in Science and Technology), the CERTAINTY project (Grant Agreement 101137680) funded by Horizon Europe program, the EarthCARE DISC project, funded by the European Space Agency under Contract No. 4000144997/24/I-NS and the AIRSENSE (Aerosol and aerosol cloud Interaction from Remote SENSing Enhancement) project, funded from the European Space Agency under Contract No. 4000142902/23/I-NS.

Thank you!

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