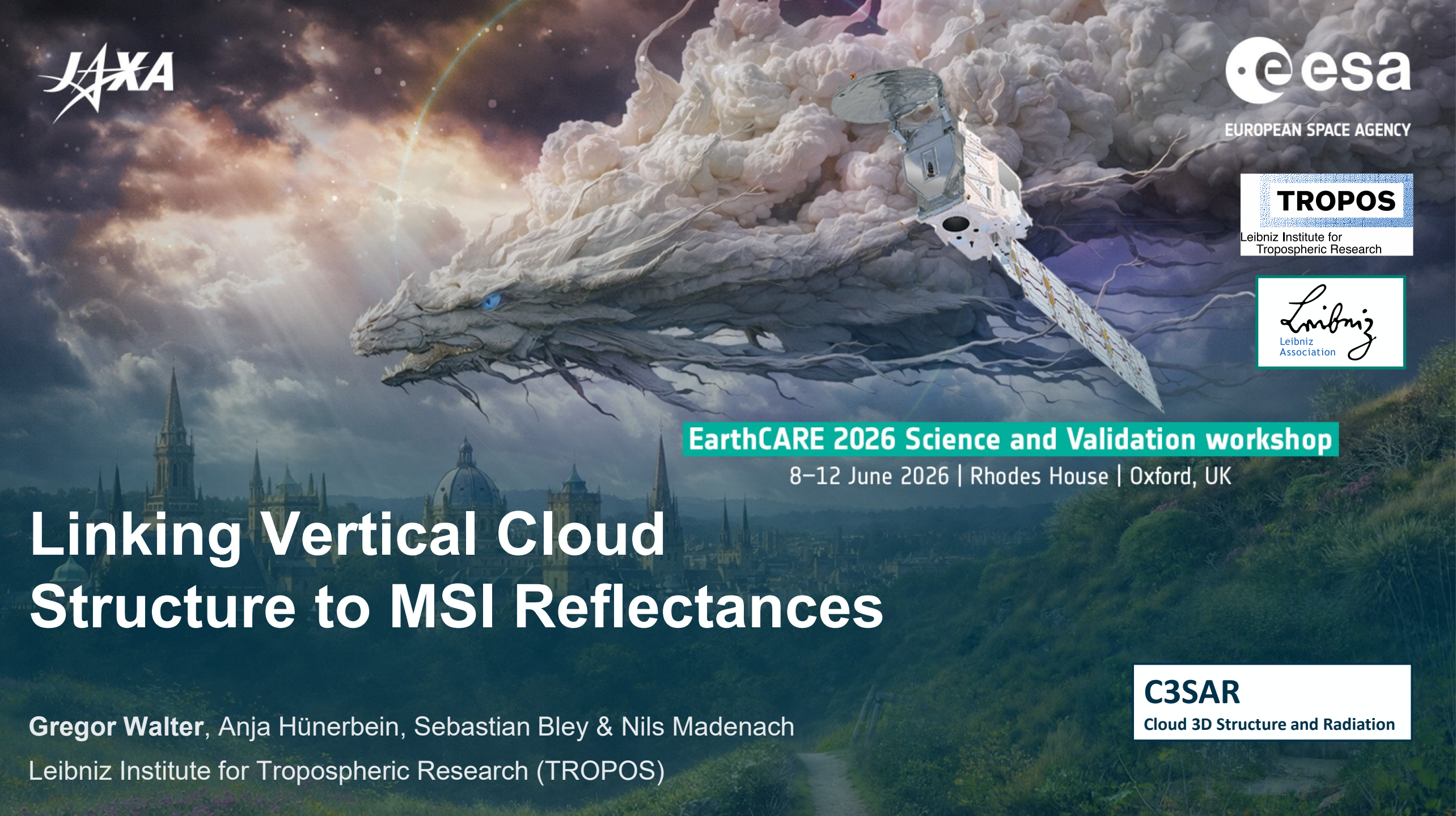

EarthCARE 2026 Science and Validation workshop

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

Linking Vertical Cloud Structure to MSI Reflectances

C3SAR
Cloud 3D Structure and Radiation

Gregor Walter, Anja Hünerbein, Sebastian Bley & Nils Madenach

Leibniz Institute for Tropospheric Research (TROPOS)

Linking Vertical Cloud Structure to MSI Reflectances

Retrieval of cloud microphysical properties with imager (e.g. MSI):

- Combination of reflective (visible/ near IR) and absorbing (SWIR) channel
- Independent pixel approximation & assumption of plane-parallel, homogeneous cloud

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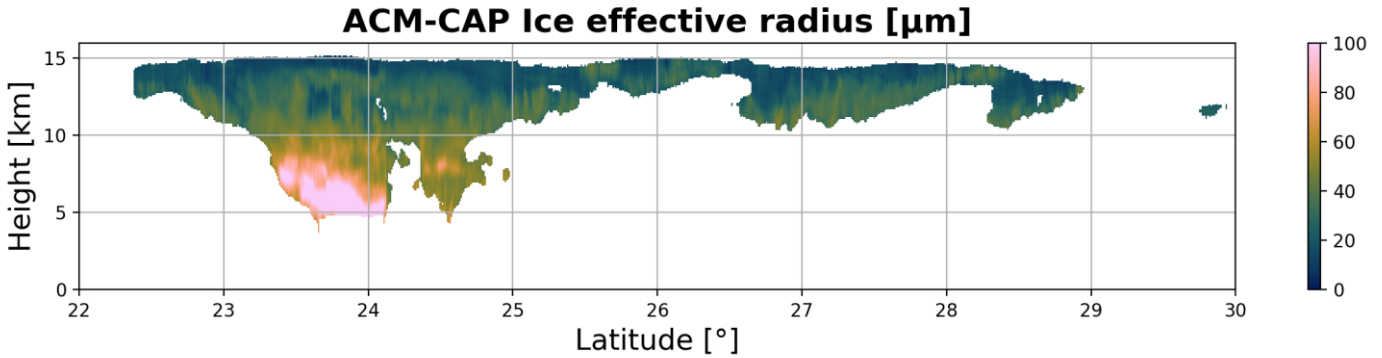
Reality:

- Vertical variability of microphysical properties



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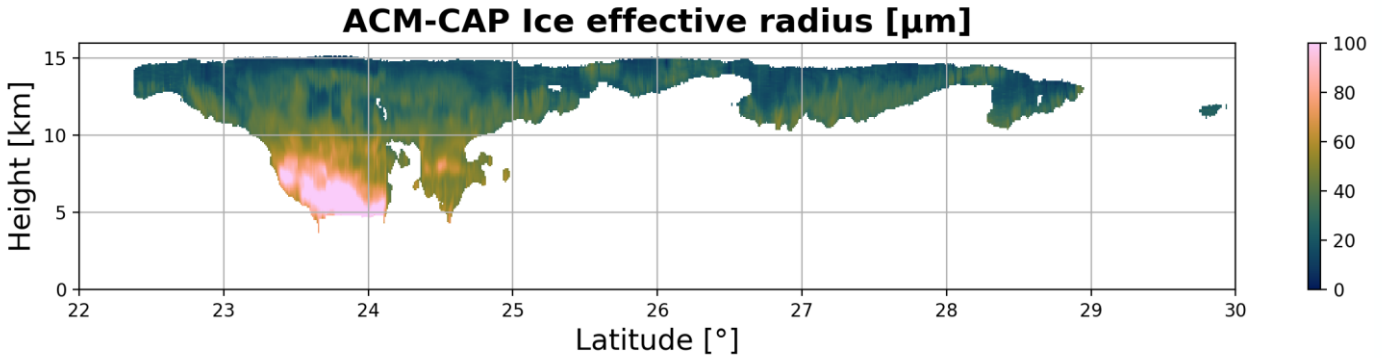
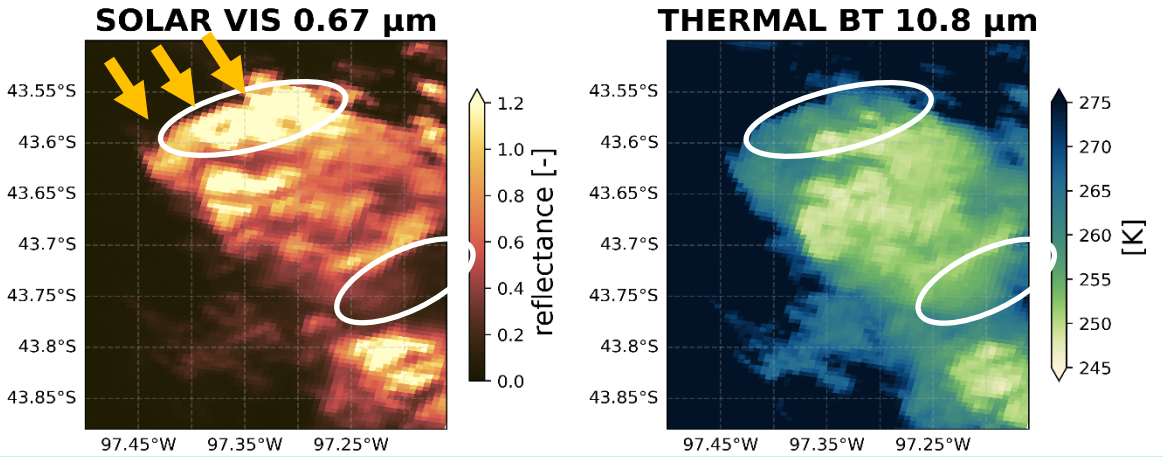


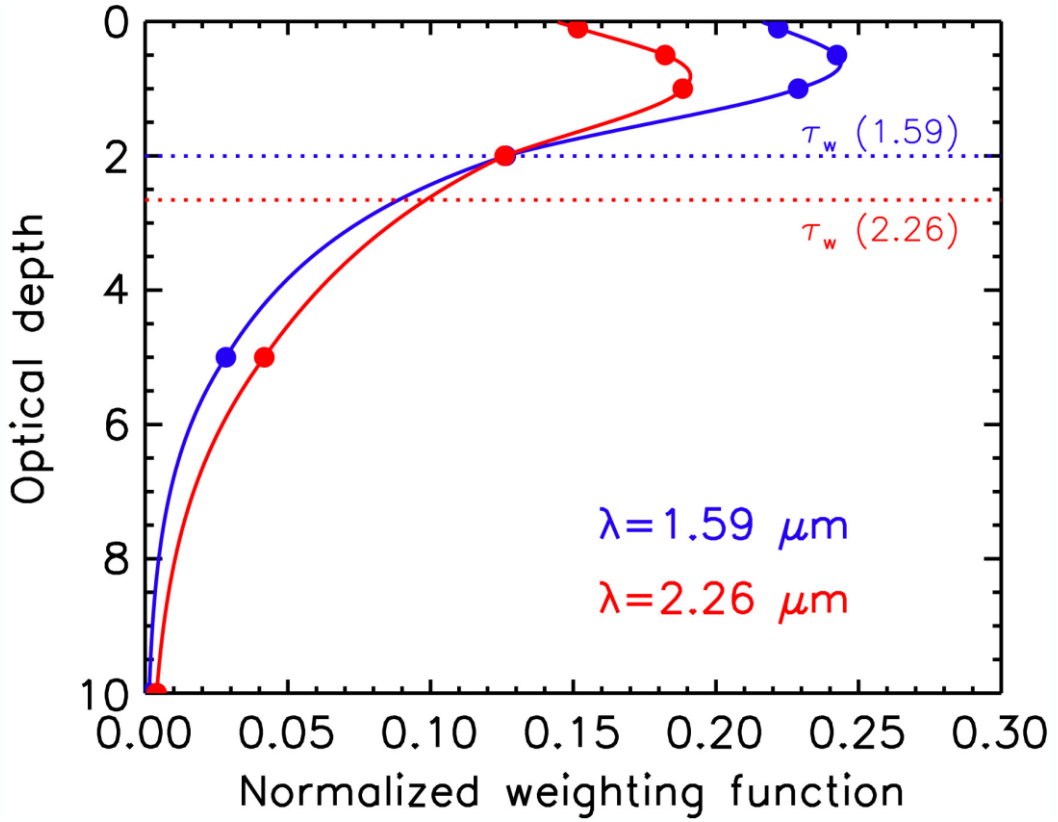
- 3D radiative effects (e.g. horizontal photon transport & side illumination/ shadowing)

… determine solar reflectances of cloudy pixels



Linking Vertical Cloud Structure to MSI Reflectances

Weighting function: Contribution of cloud levels on imager channels



Diedenhoven et al., 2016

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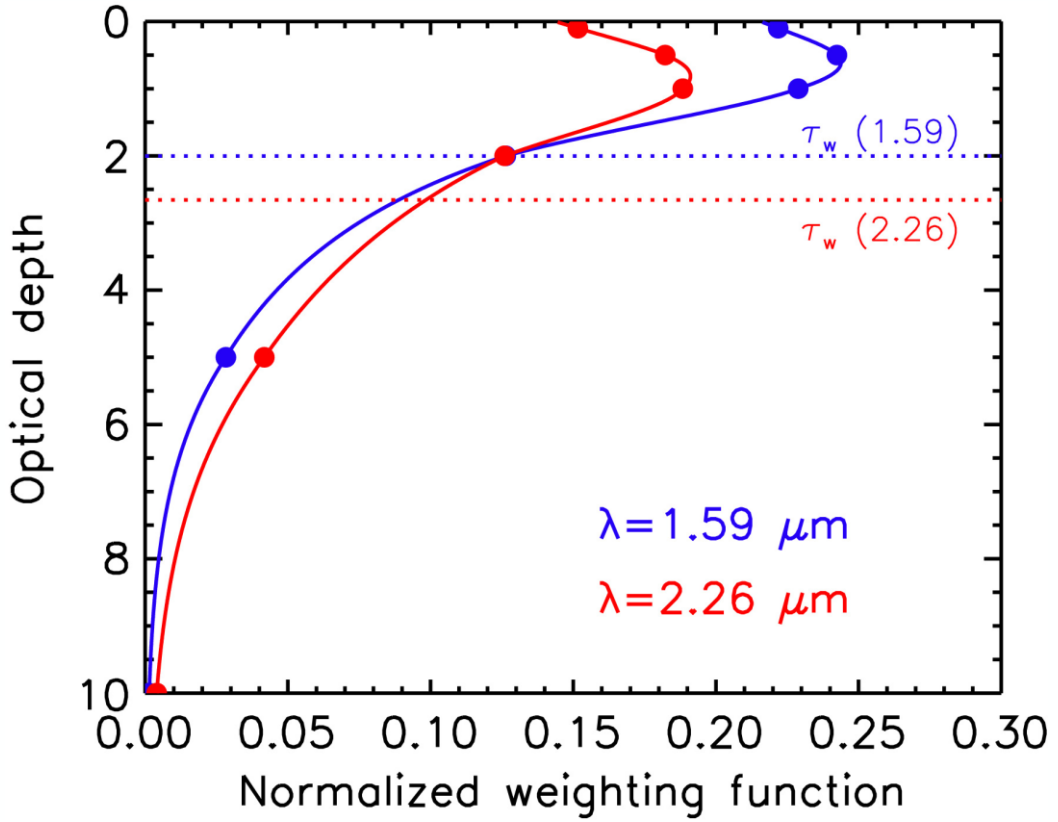

Diedenhoven et al., 2016

Can we extract more information from the imager than just column-integrated cloud properties?

How do vertical profiles of ACM-CAP correspond to MSI measurements?

Linking Vertical Cloud Structure to MSI Reflectances

DATA: 6 months of ACM-CAP, MSI-RGR and MSI-COP I baseline BC

ACM-CAP:

- **Vertical profiles** of microphysical cloud properties
- Radar **(CPR)**, Lidar **(ATLID)** & Imager **(MSI)**

MSI channels:

- 4 solar channels (**VIS**, **NIR** and two **SWIR** channels)
- 3 thermal channels

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MSI channels:

- 4 solar channels (**VIS**, **NIR** and two **SWIR** channels)
- 3 thermal channels

Cloud pixel selection:

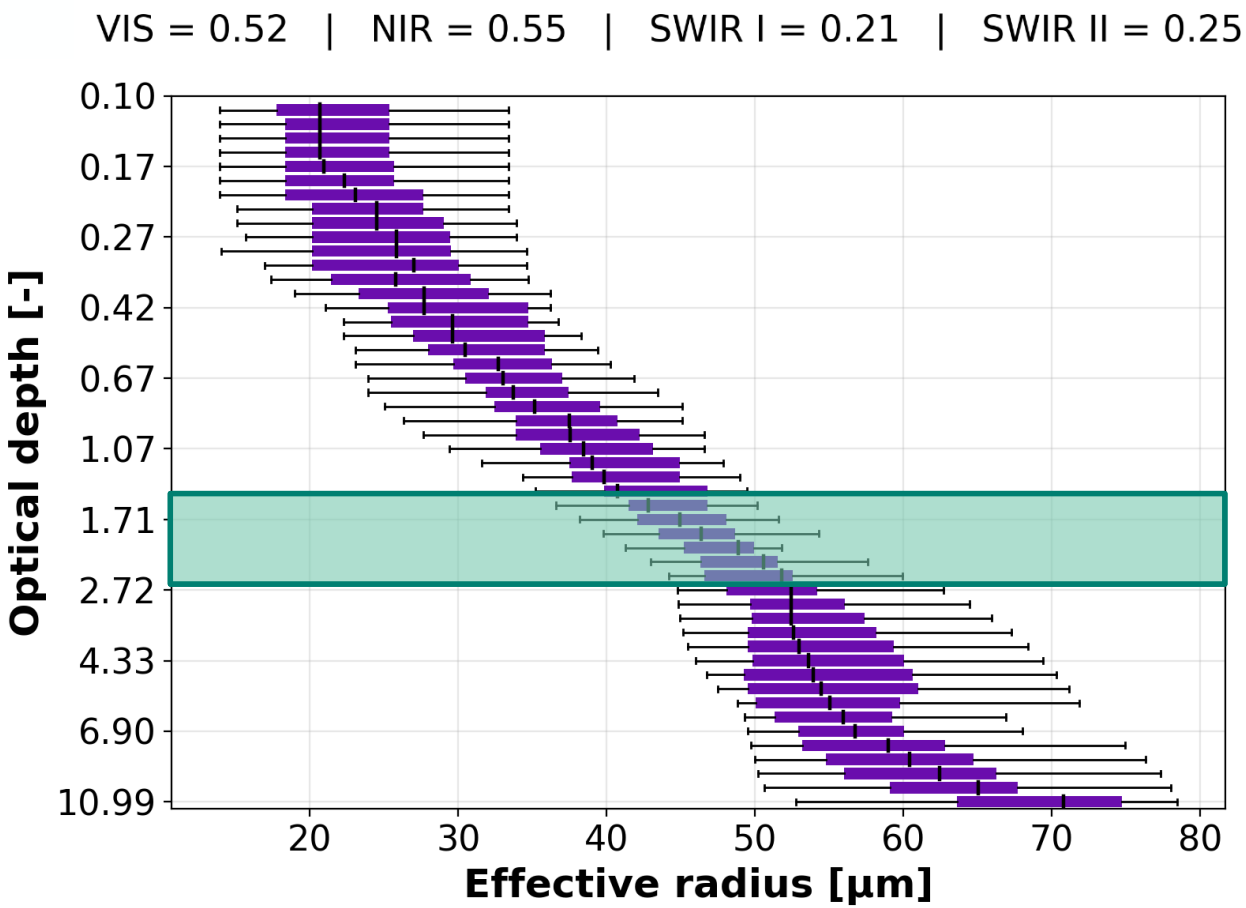
- Pure **ice cloud**
- Ocean
- Low 3D effects

Goal:

- Link vertical profiles of effective radius and ice water content to MSI reflectances
- Enhance information gain from imager

Linking Vertical Cloud Structure to MSI Reflectances

Results: Multiple profile structures for same set of reflectances



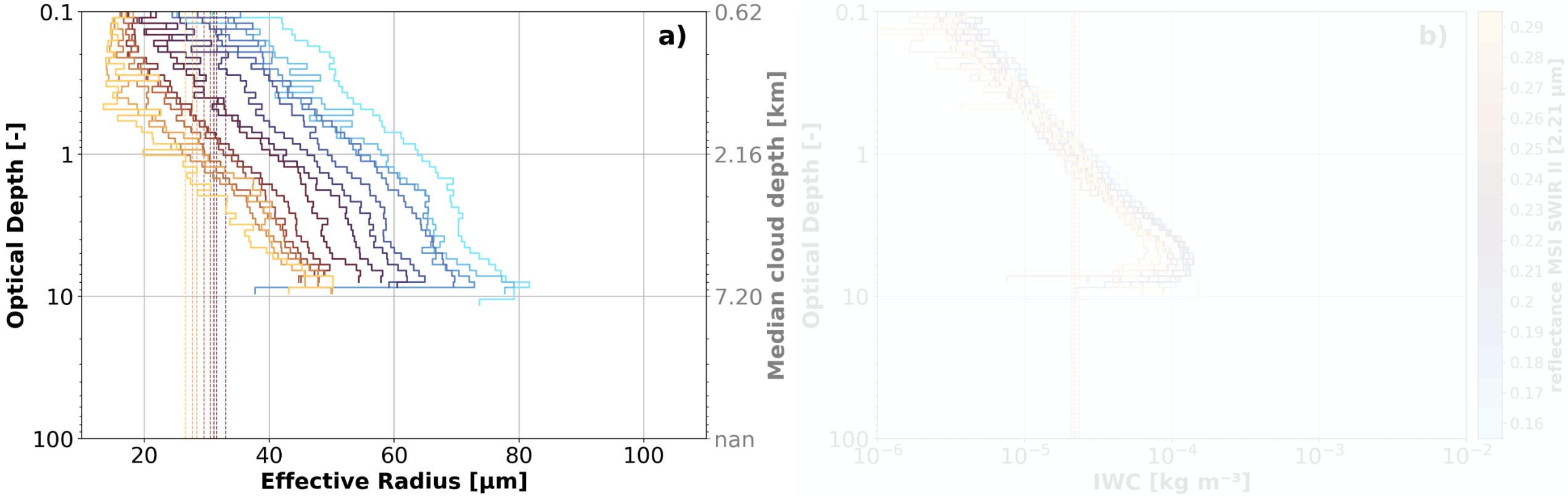
- **Fixed** MSI **reflectances**
- 17 cases with **same combination**
- Clouds regridded **from geometrical height** to **optical depth** levels
- Lowest variability around an **optical depth** of **2** caused by **weighting** of different levels

Linking Vertical Cloud Structure to MSI Reflectances

Results: Larger particles produce lower SWIR reflectances

fixed MSI **VIS** & MSI **SWIR II variability**:

reflectance MSI VIS [0.67 µm] = 0.46 | color: MSI SWIR II [2.21 µm]



-> **Agreement** of **ACM-CAP effective radius** with **MSI SWIR** reflectances

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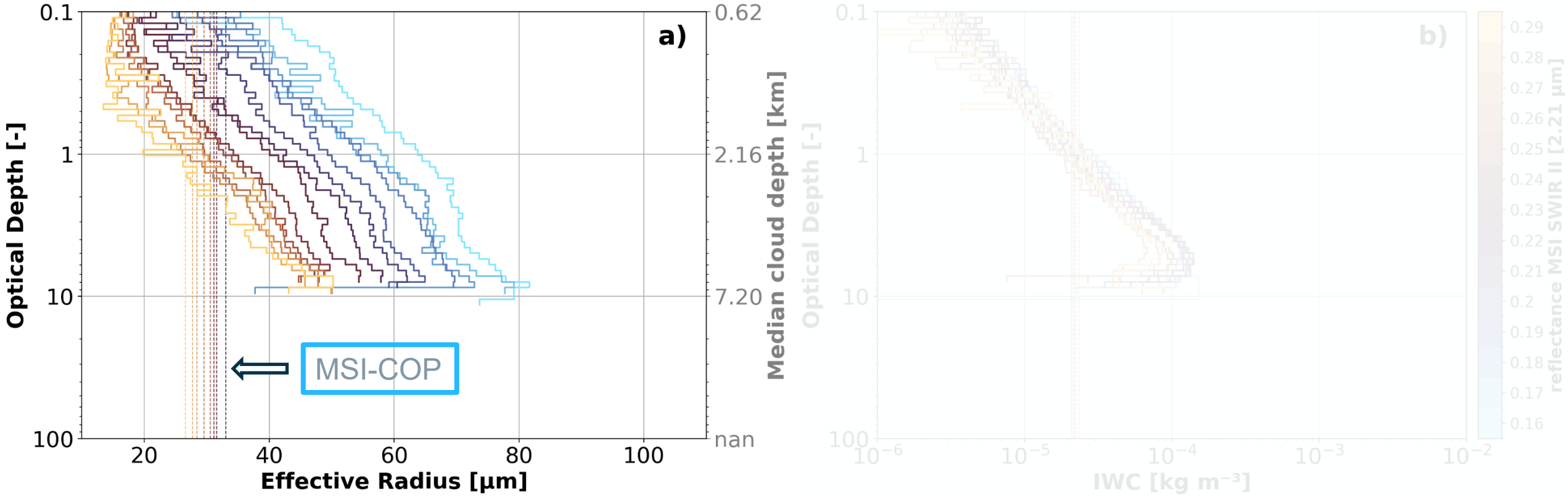

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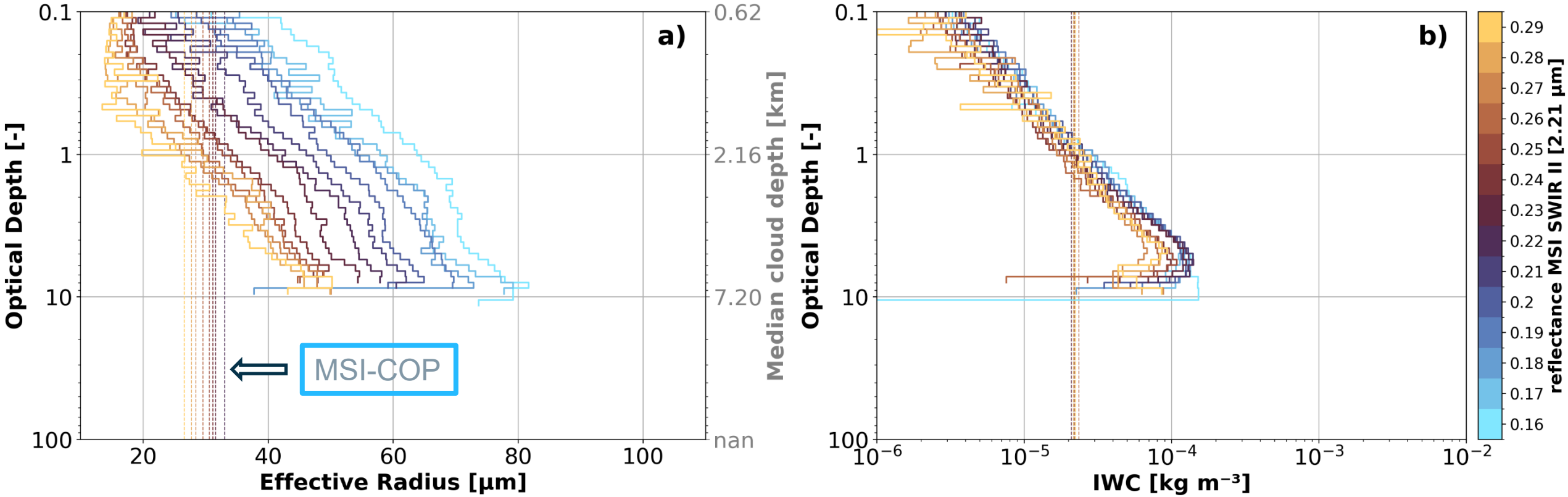

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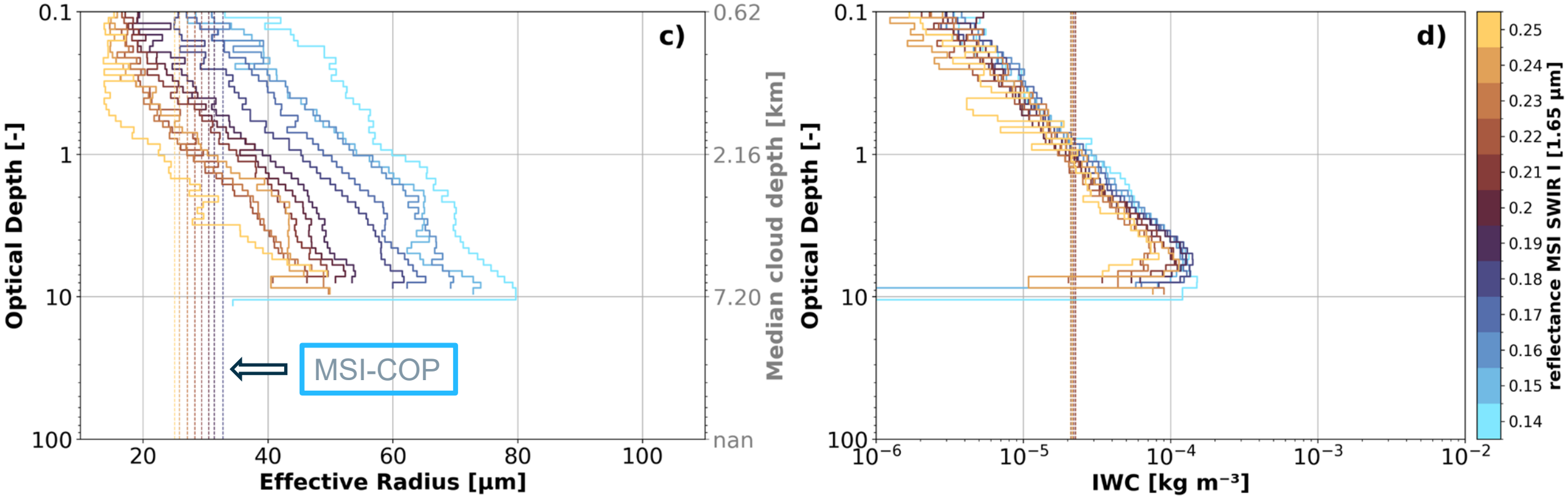

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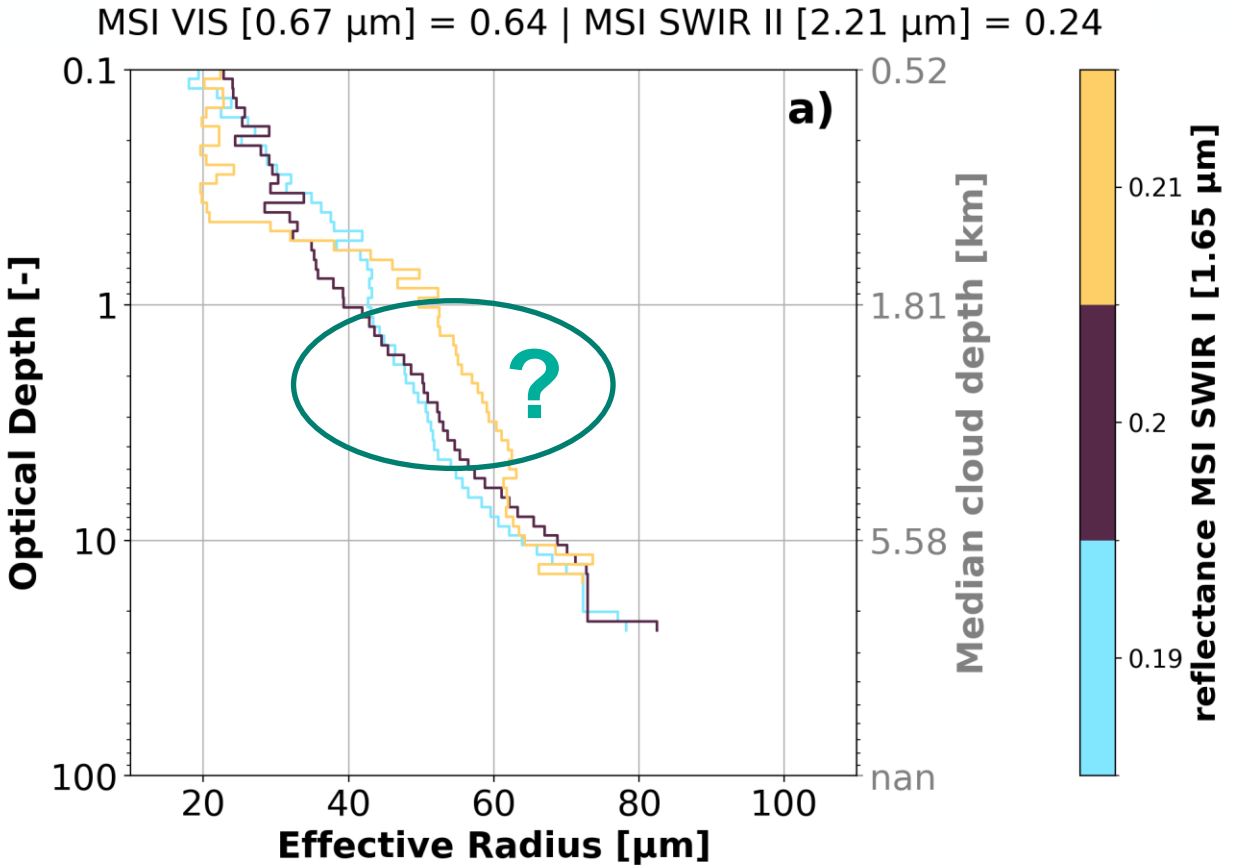
Linking Vertical Cloud Structure to MSI Reflectances

Results: fixed MSI **VIS** & **SWIR** reflectance & remaining **SWIR** variability



- **Unexpected higher effective radius** for **higher SWIR I -> No explanation yet**
- **Higher effective radius** for **lower SWIR II -> expected**

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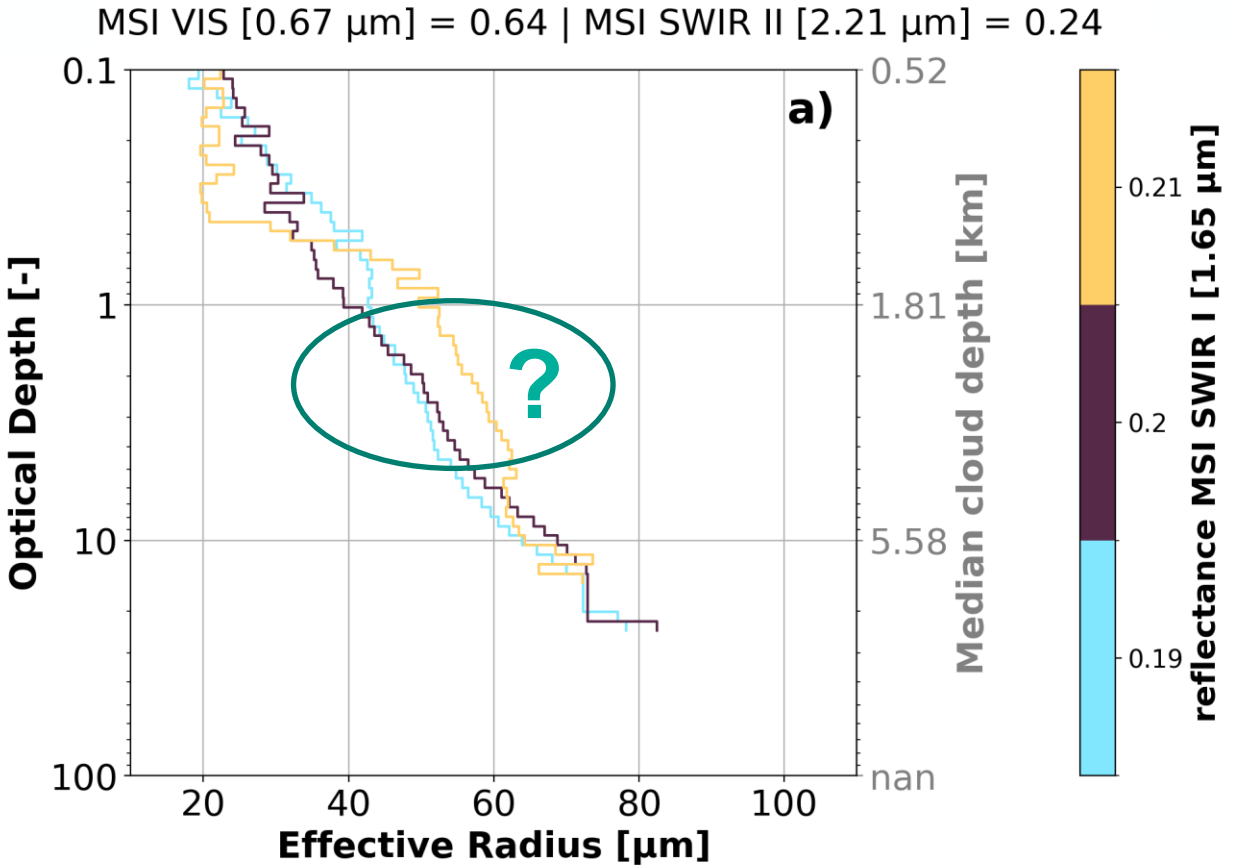

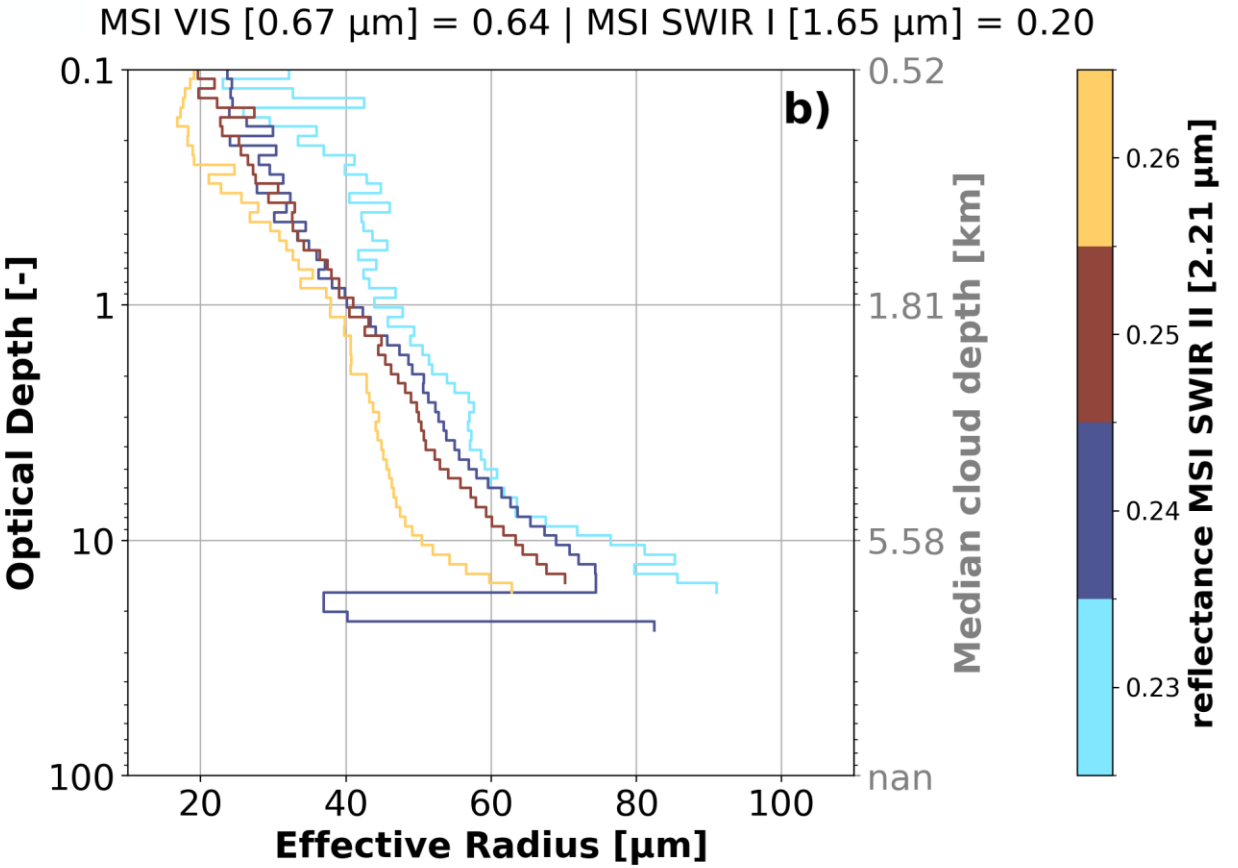

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Linking Vertical Cloud Structure to MSI Reflectances

Preliminary results: Modelled vertical effective radius and ice water path across different optical depth levels

INPUT: MSI (L1)

- All reflectances and brightness temperatures
- Solar and observational geometries
- Horizontal structure parameters

TARGET: ACM-CAP effective radius and ice water content

- 24 levels of optical depth trained in ensemble (random forest as baseline)
- Trained on individual profiles, re-grided on optical depth

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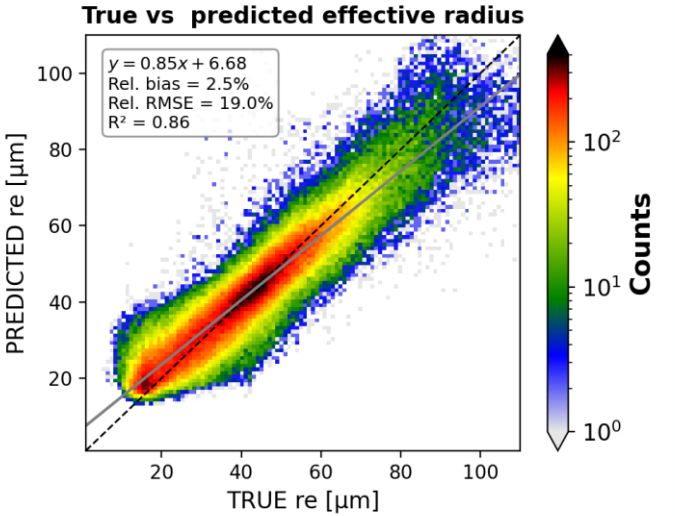

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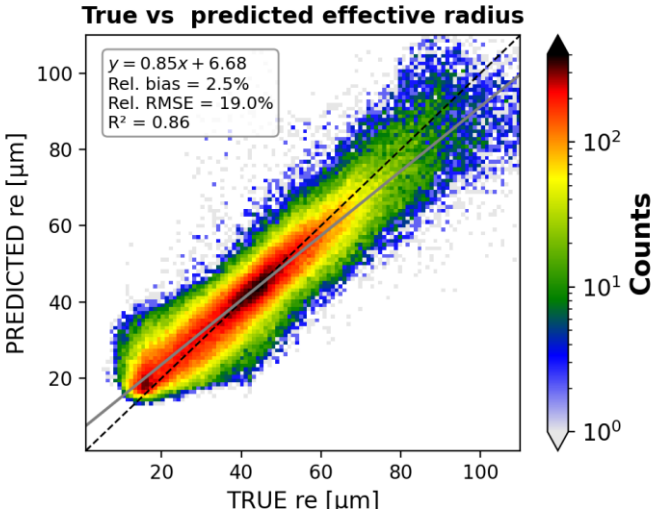
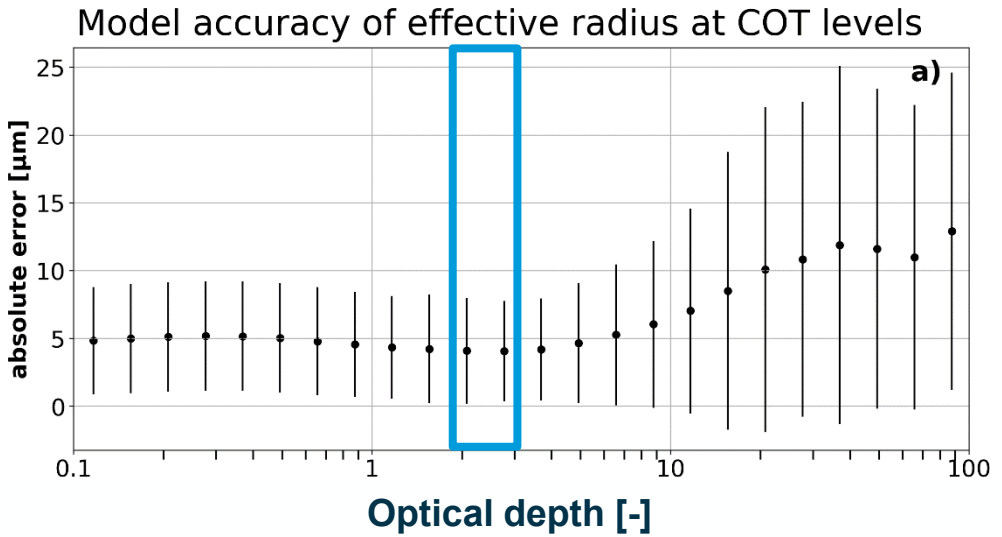
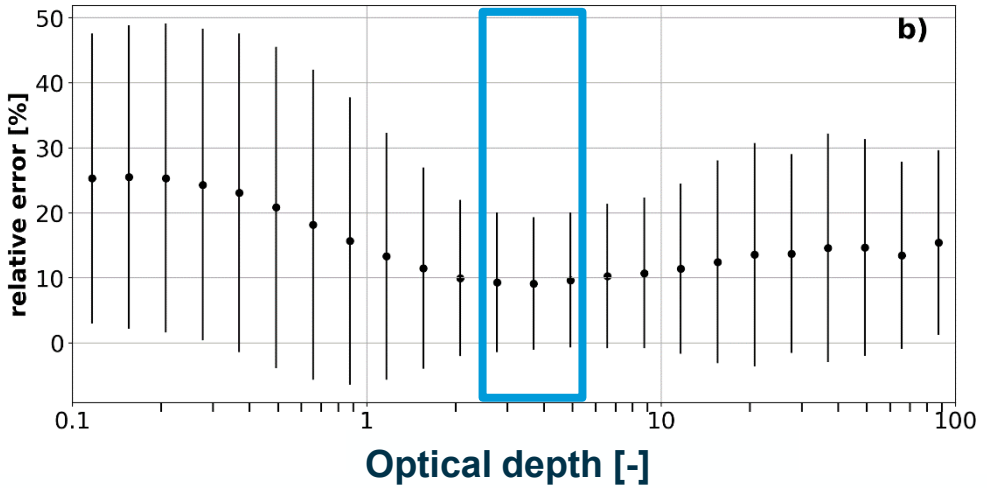


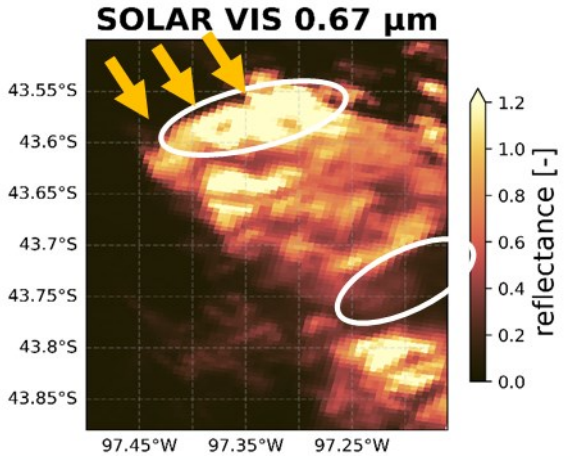


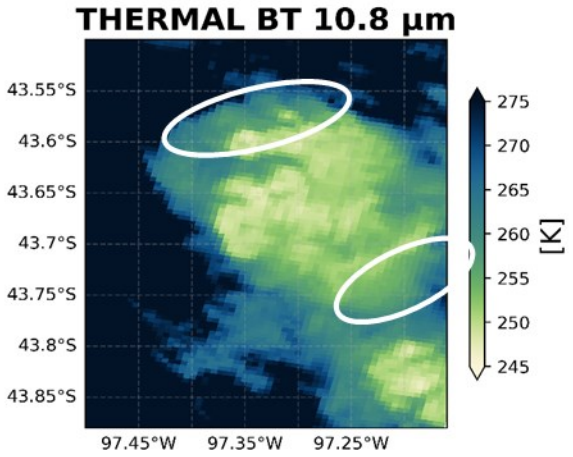


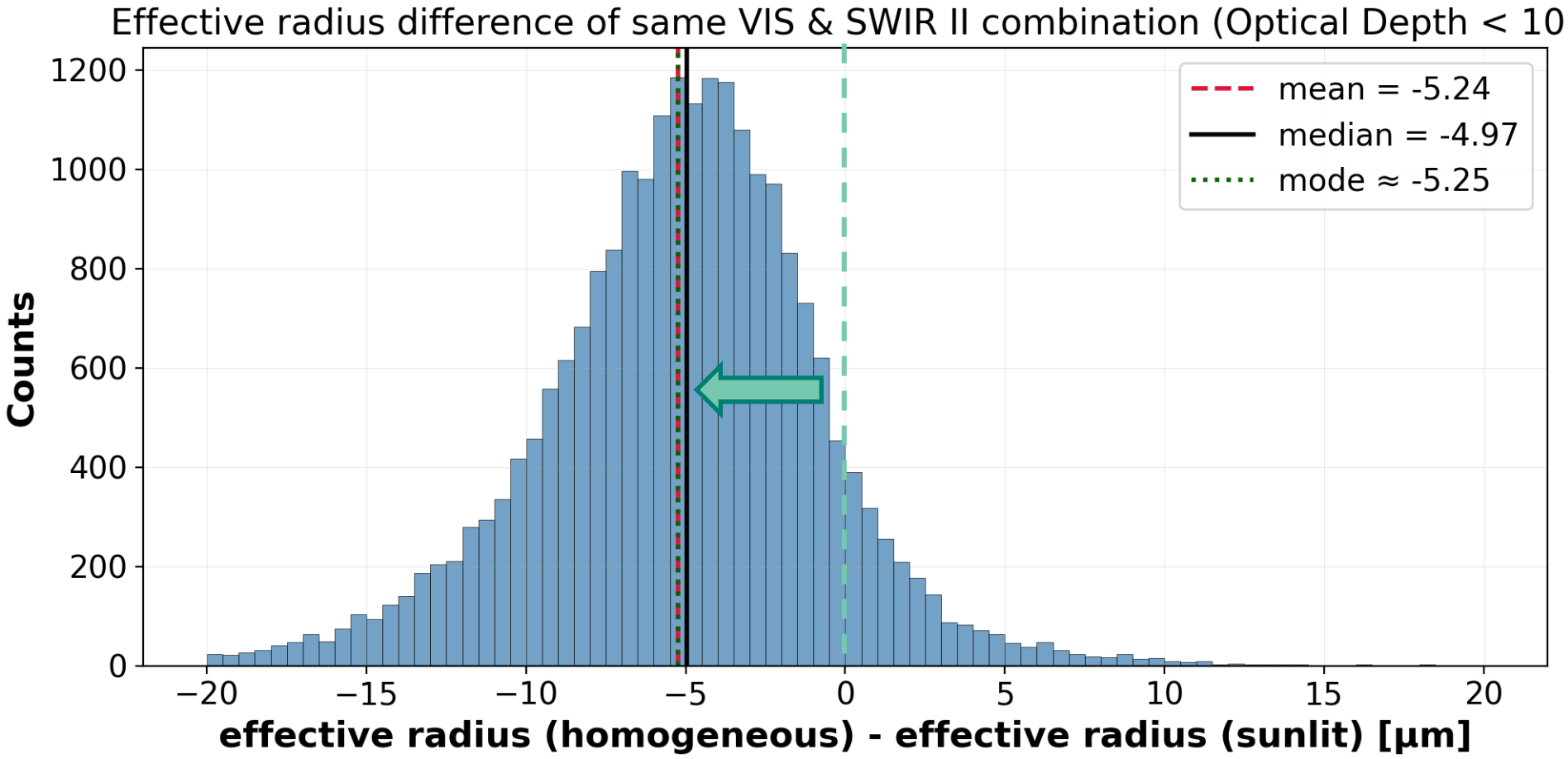
Highest accuracy at COT of 2 to 4 -> expected from weighting functions

Linking Vertical Cloud Structure to MSI Reflectances

Results: Tilted cloud slopes can enhance reflectances (3D effect)







Low reflectance (larger particles)
+ Illuminated pixel (tilted slope)

same reflectance as horizontally homogeneous pixel with smaller particles

Linking Vertical Cloud Structure to MSI Reflectances

SUMMARY:

- **MSI** contains **information** about **vertical structure** BUT **under-constrained**
- **Weighting function** recognizable in ACM-CAP **effective radius profiles**
- **Higher MSI SWIR** correlates with **lower effective radii** in **ACM-CAP** (& vice versa)
- MSI model to retrieve effective radius & ice water content:
  reproduces variability in data/ weighting function
  -> Current version only as baseline
- Next step:
  -> **More information** in **horizontal structure** of clouds? -> Link to 3D reconstruction