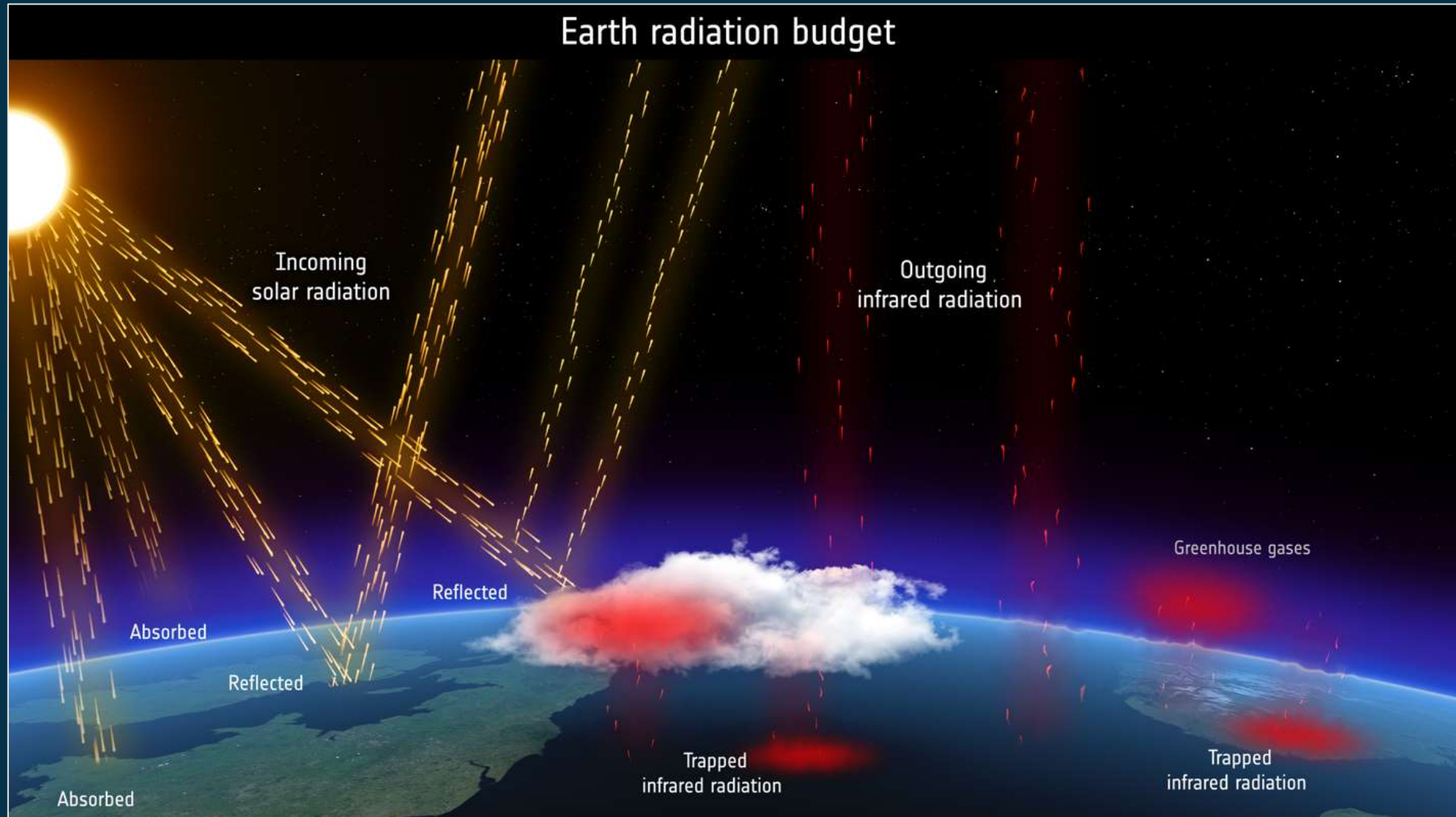


A New View of Clouds: Insights from EarthCARE and AI

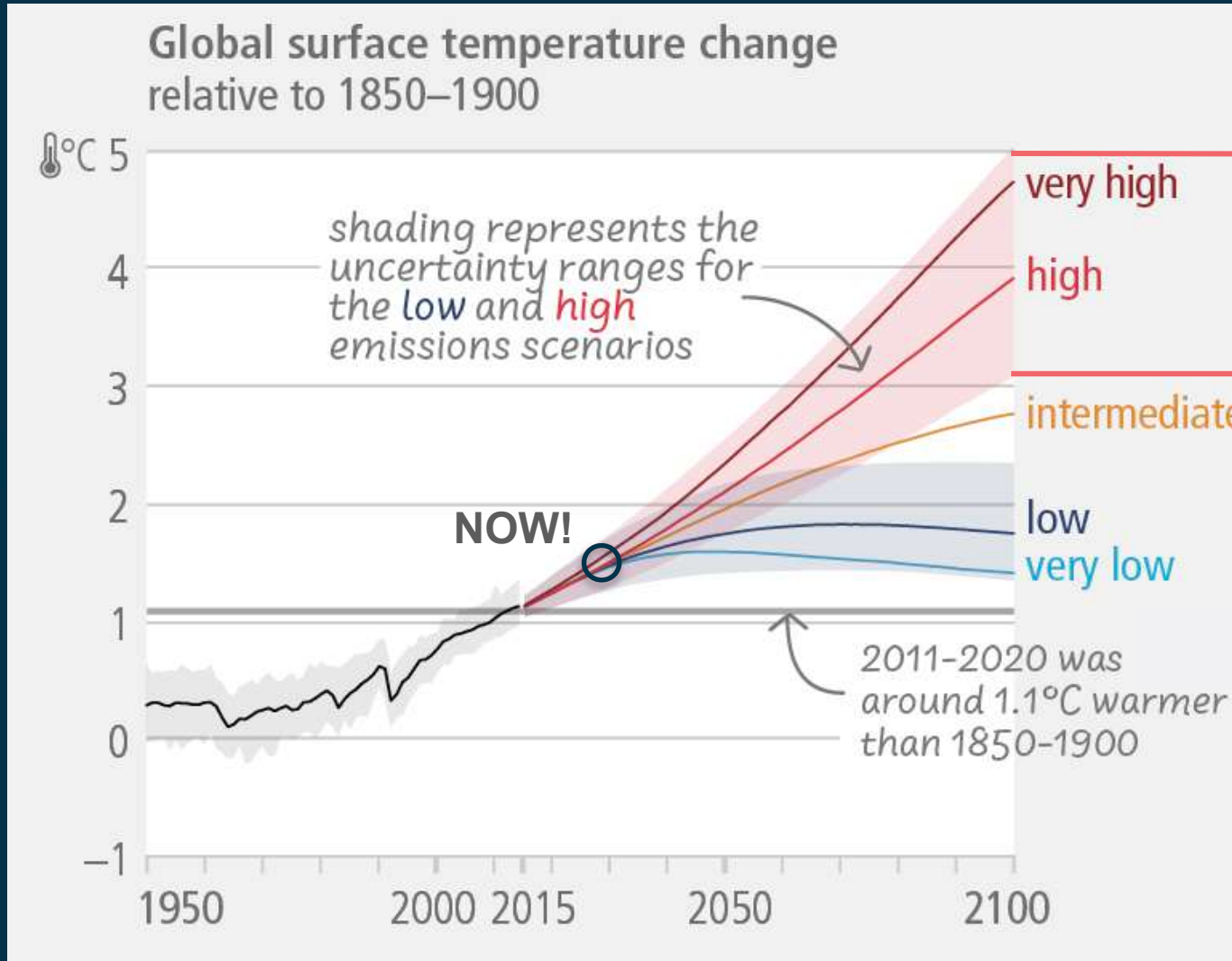
Johanna Mayer

19/06/2026

Clouds impact the Earth's radiation budget



Cloud feedbacks are the largest uncertainty in climate predictions

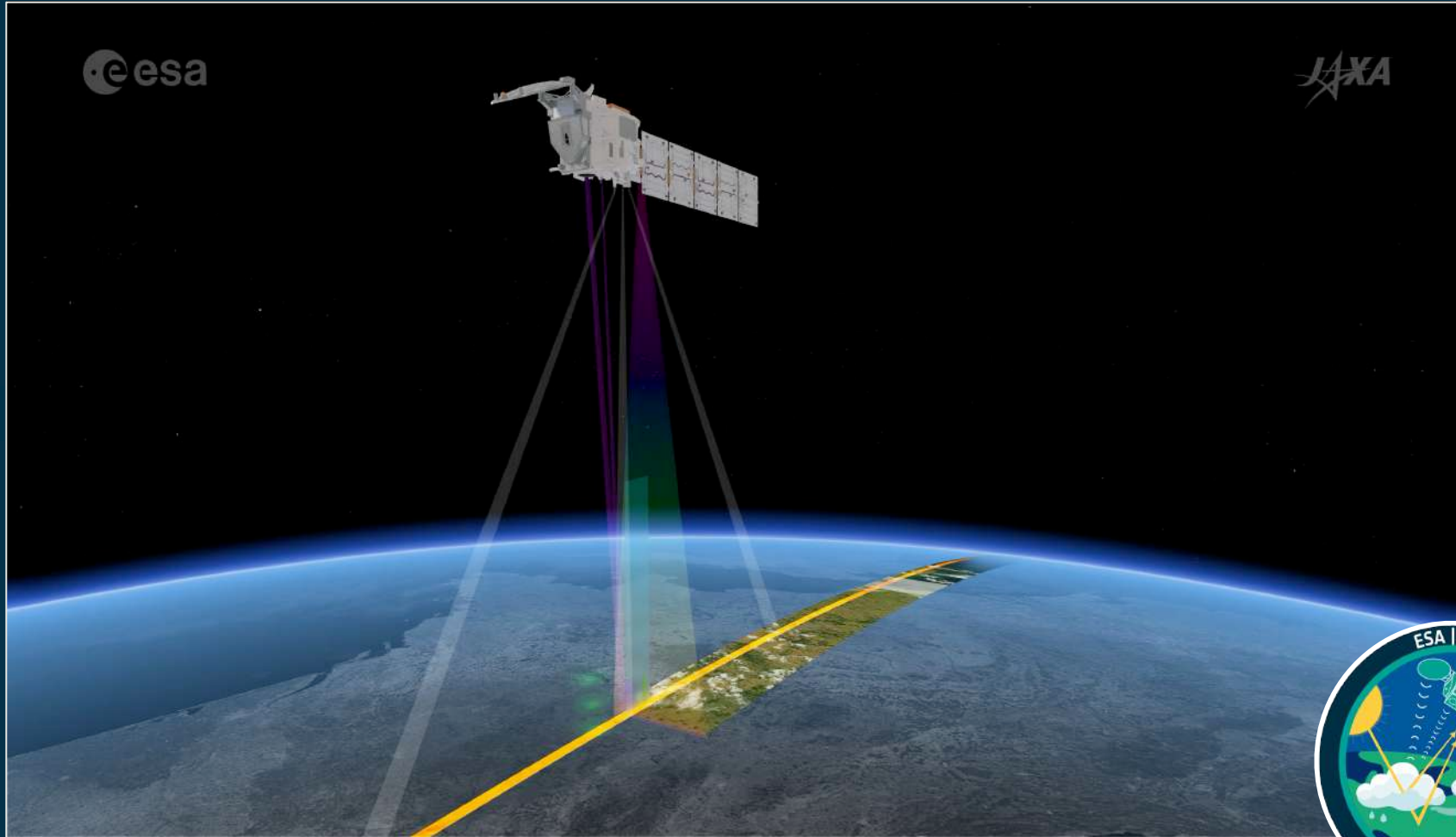


→ +5°C if clouds amplify the warming, a positive cloud feedback

→ +3°C if clouds stay about the same

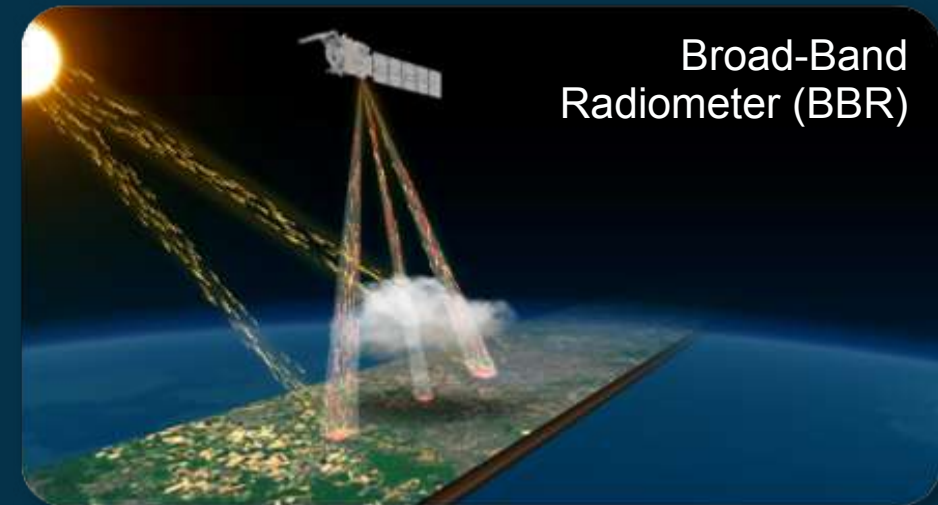
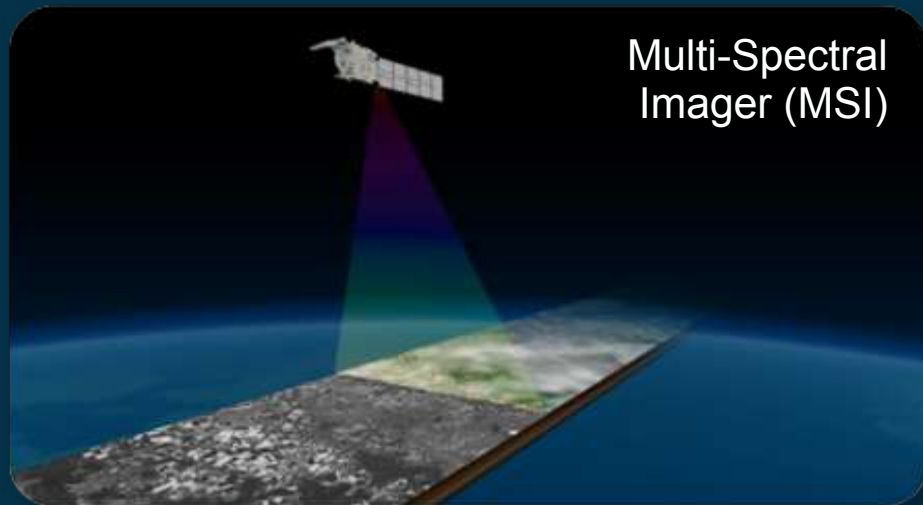
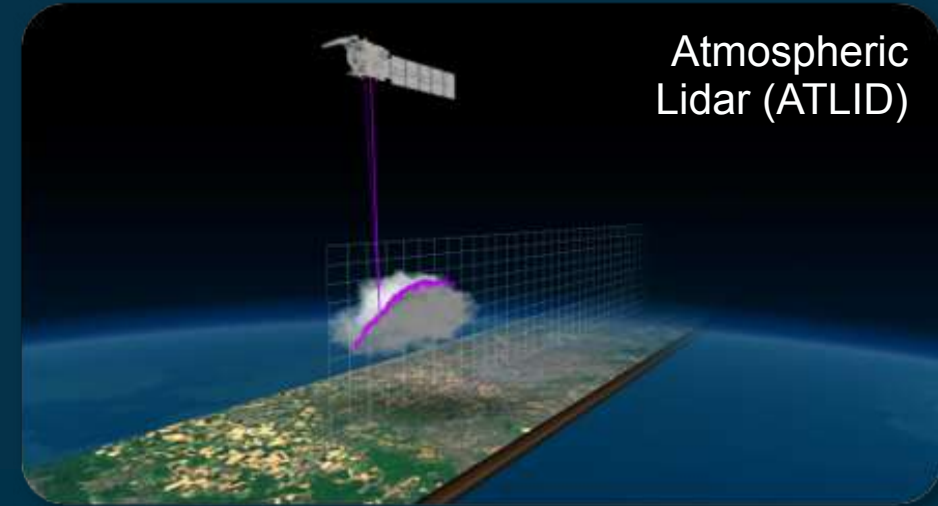
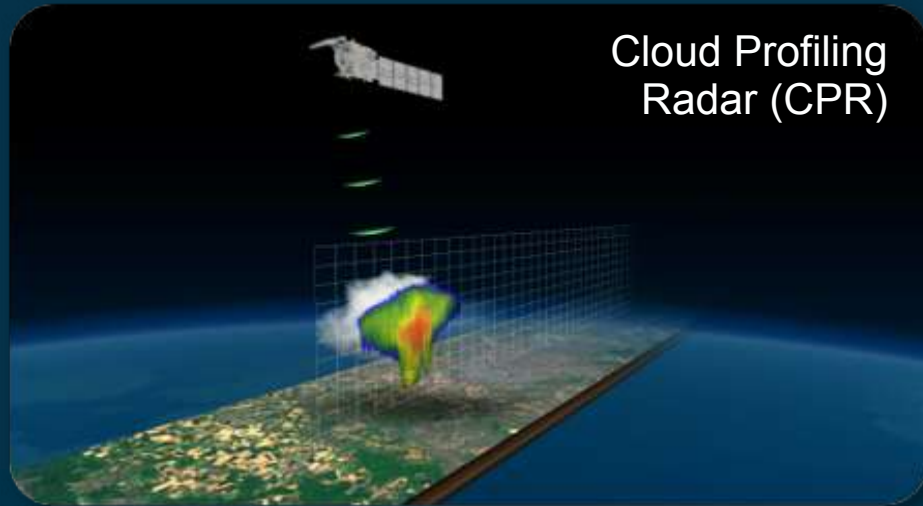
IPCC report 2023

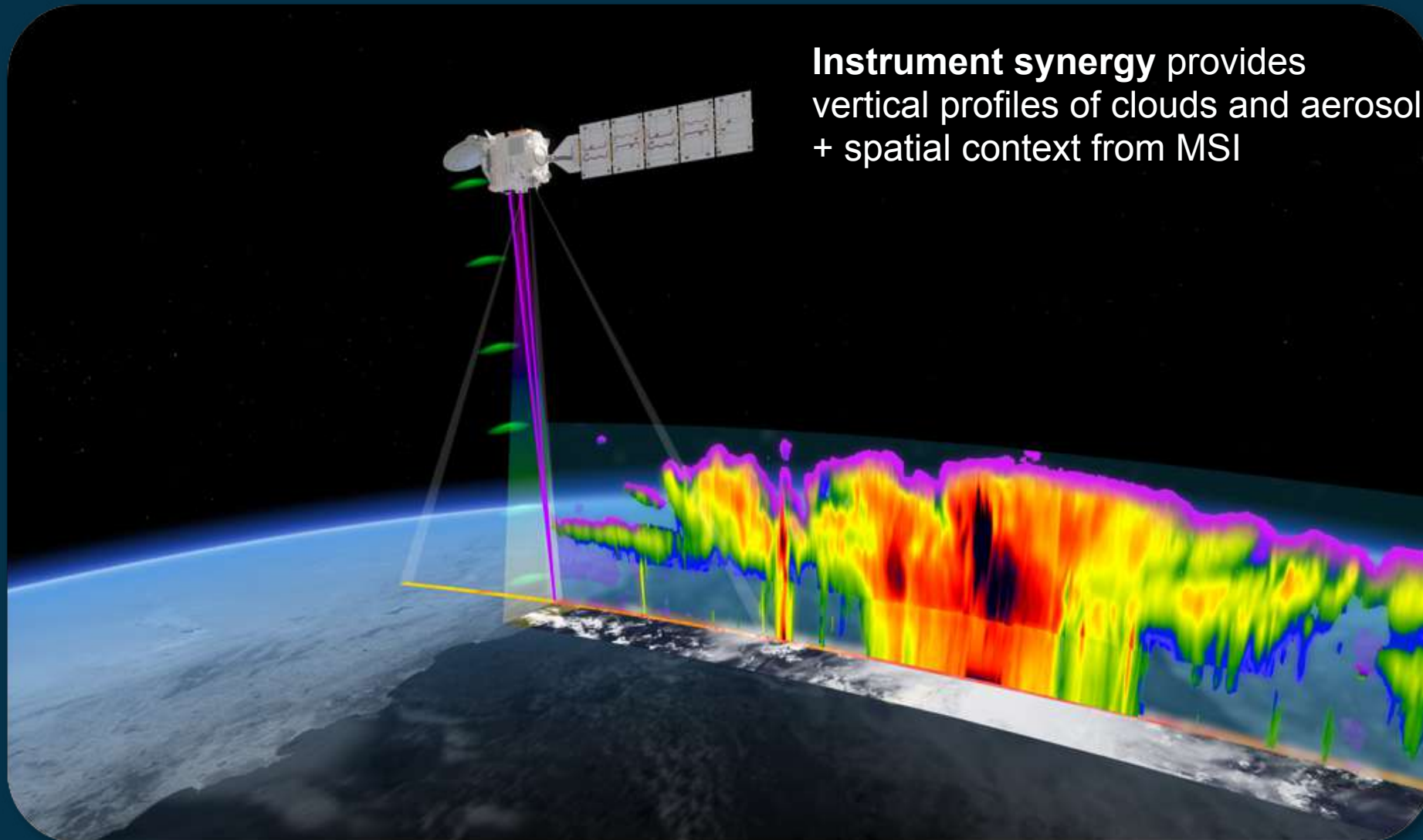
Introduction to EarthCARE



- Joint ESA and JAXA mission
- Launched in May 2024
- Mission objective: Systematic provision of vertical profiles of clouds and aerosols, collated with measurements of solar and emitted thermal radiation.







How can we use AI methods to make the best use of EarthCARE observations?

+ synergies with other satellites

EarthCARE + AI methods

Lightning prediction

Blanka Piskala Gvozdkova¹

Cloud structure detection

Johanna Mayer¹

3D cloud reconstruction

Shirin Ermis⁷, Cesar Aybar², Lilli Freischem⁷,
Stella Girtsou^{3,4}, Kyriaki-Margarita Bintsi^{5,6},
Emiliano Diaz Salas-Porras², Michael
Eisinger¹, William Jones⁷, Anna Jungbluth¹,
Benoit Tremblay⁸

Connect EarthCARE with lightning activity



Connect EarthCARE with lightning activity

Number of lightning groups around CPR track
(± 2.5 min, ± 2.5 km)

✂ Storm summary

EC orbit-frame: 05592A

Lightning source: GLM

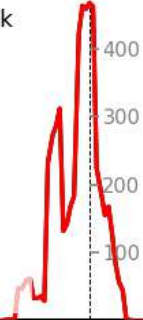
Time: 2025-05-23 08:08

Dist. of CPR from storm center: 7.2 km

Storm lightning counts: 1281

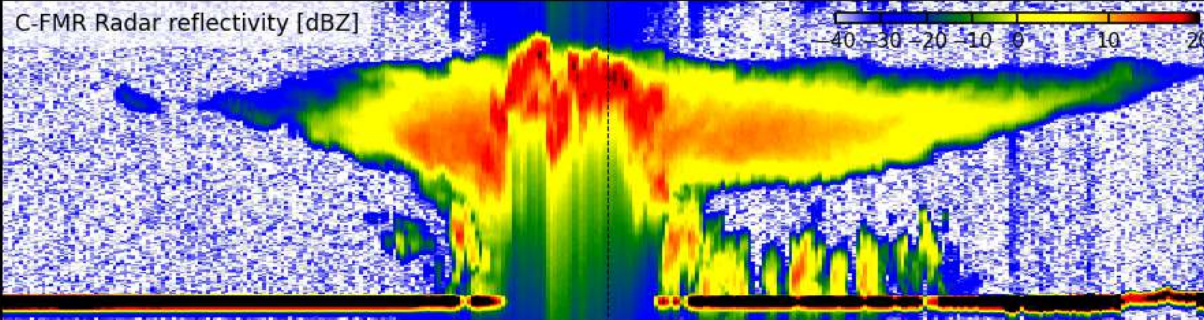
Peak lightning counts: 467

Peak lon/lat: -94.84°, 15.33°



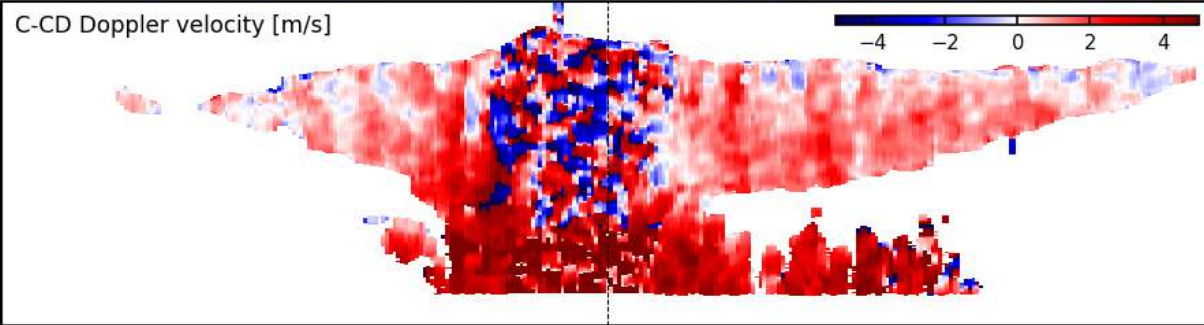
Lightning
imager

C-FMR Radar reflectivity [dBZ]



EarthCARE
cloud
profiles

C-CD Doppler velocity [m/s]



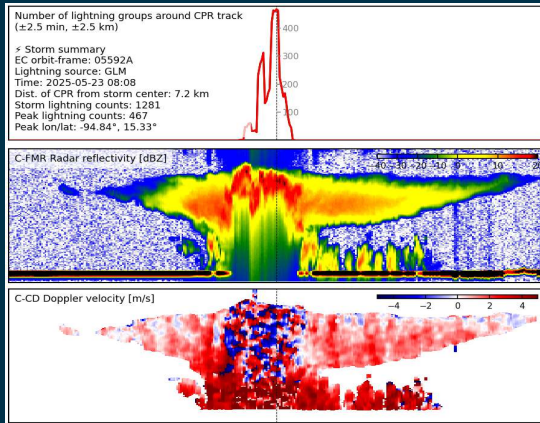
Goal: Use AI model to predict lightning activity from EarthCARE vertical profiles

- which EarthCARE variables contribute most to the prediction?
- improve lightning parameterizations in weather models

EarthCARE + AI methods

Lightning prediction

Blanka Piskala Gvozdkova¹



Cloud structure detection

Johanna Mayer¹

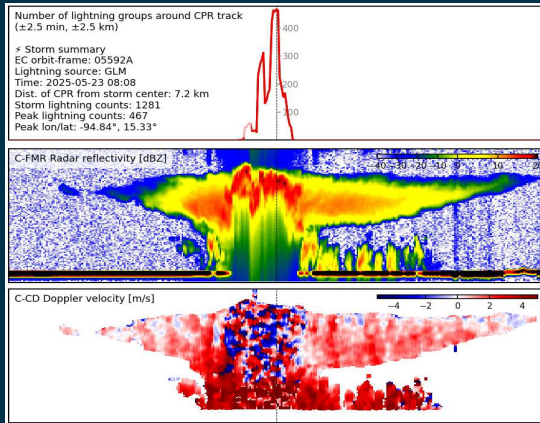
3D cloud reconstruction

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Benoit Tremblay⁸

EarthCARE + AI methods

Lightning prediction

Blanka Piskala Gvozdkova¹



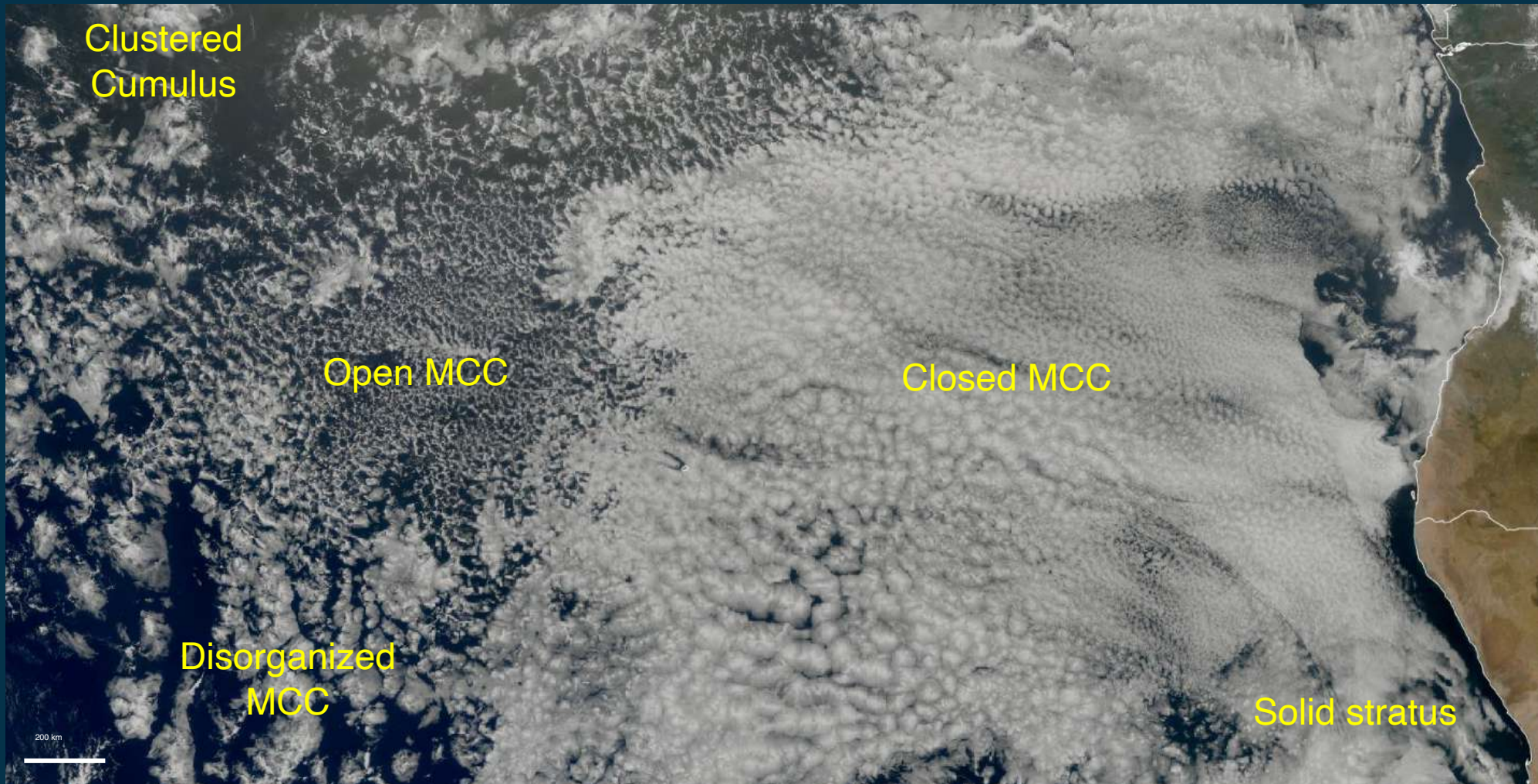
Cloud structure detection

Johanna Mayer¹

3D cloud reconstruction

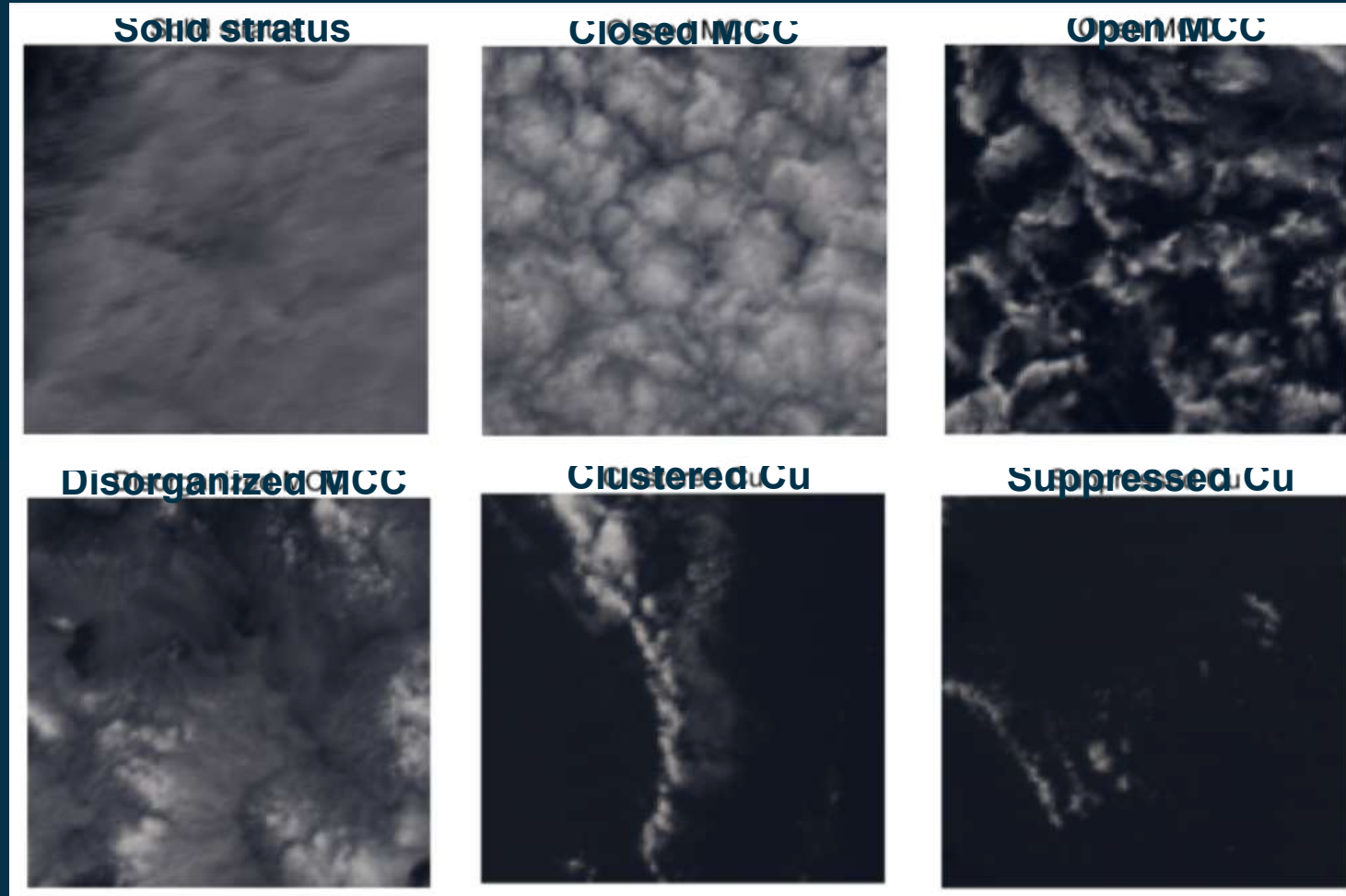
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Benoit Tremblay⁸

Clouds can organize into different structures



Wood et al. (2006), Yuan et al (2020), Wu et al. (2025)

Detect cloud structures using a Neural Network



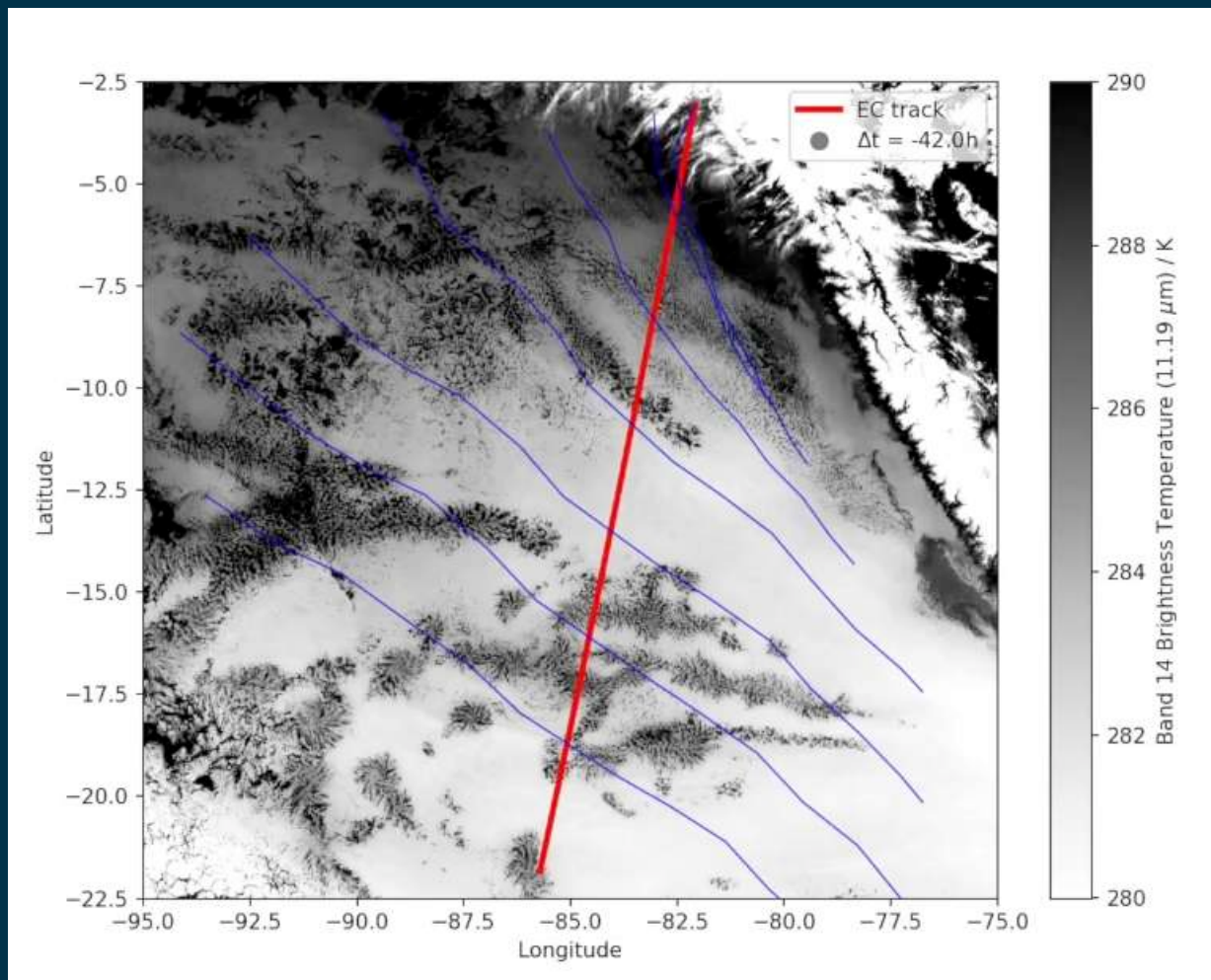
Using AI methods
(Convolutional Neural
Network; ResNet50) we
can classify clouds into
typical structures

Adapted from Wu et al. (2025)

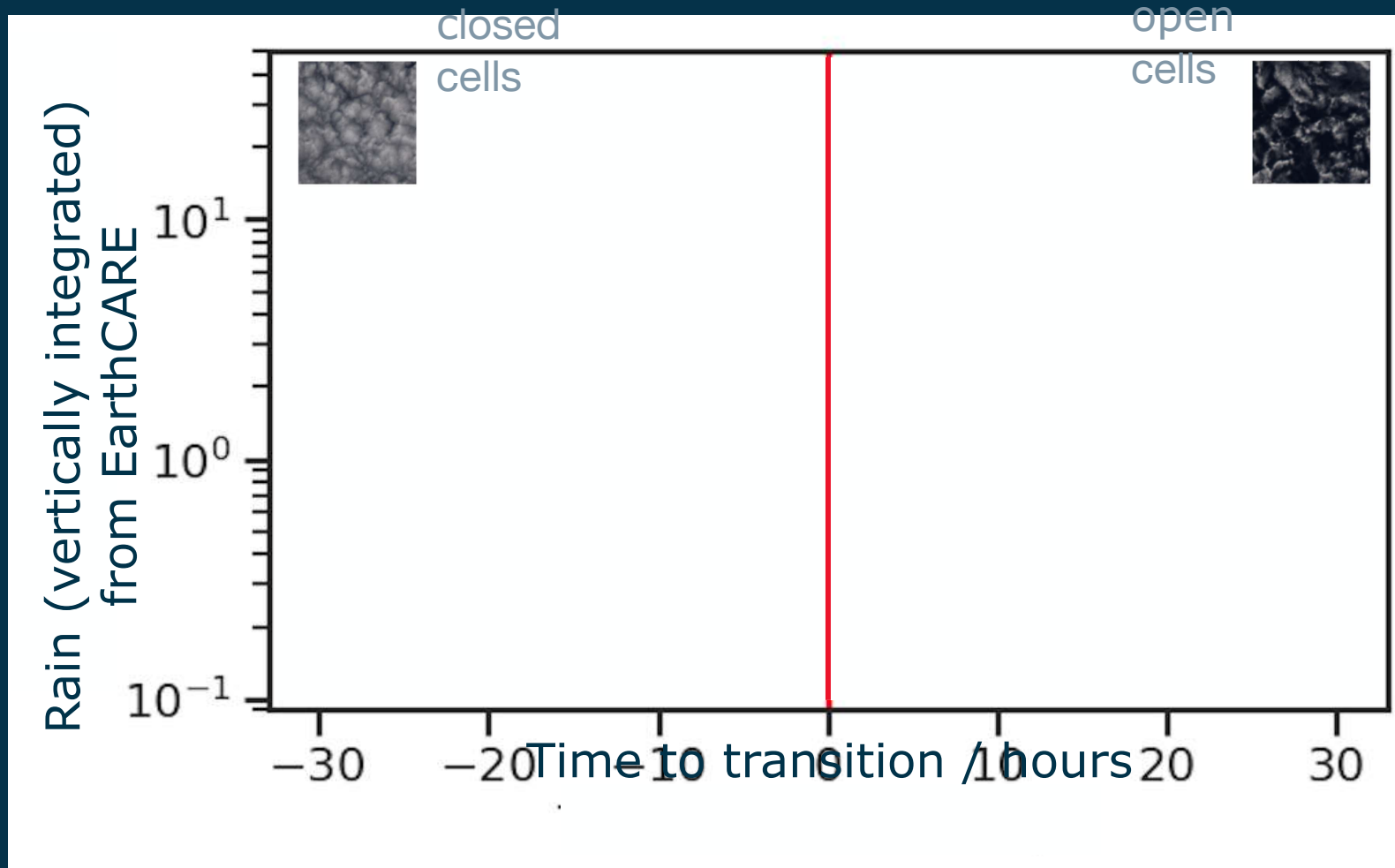
Combine with geostationary imager to get time evolution and detect cloud transitions using the CNN

CNN Category

- Closed MCC
- Open MCC
- Other structure
- No retrieval



What happens at cloud structure transitions?

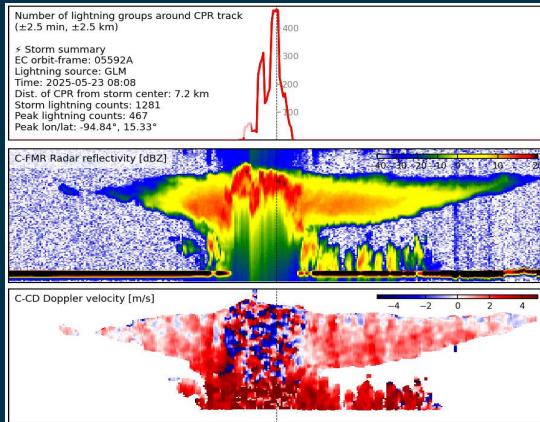


- New insights into the processes that lead to transitions between cloud structures
- implications for their climate effect

EarthCARE + AI methods

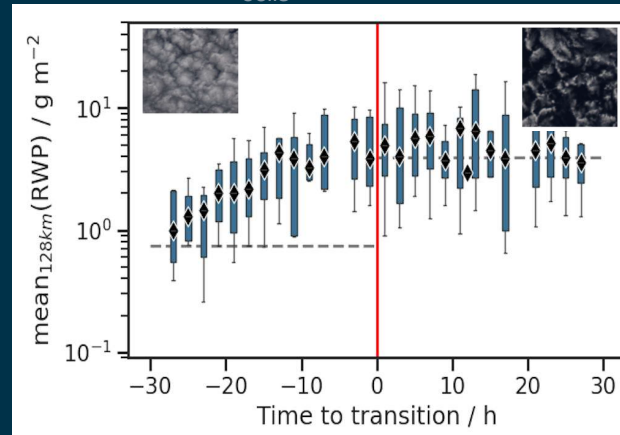
Lightning prediction

Blanka Piskala Gvozdkova¹



Cloud structure detection

Johanna Mayer¹
closed cells open cells



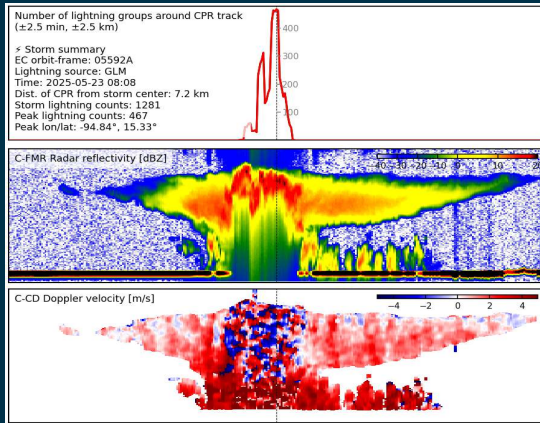
3D cloud reconstruction

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Benoit Tremblay⁸

EarthCARE + AI methods

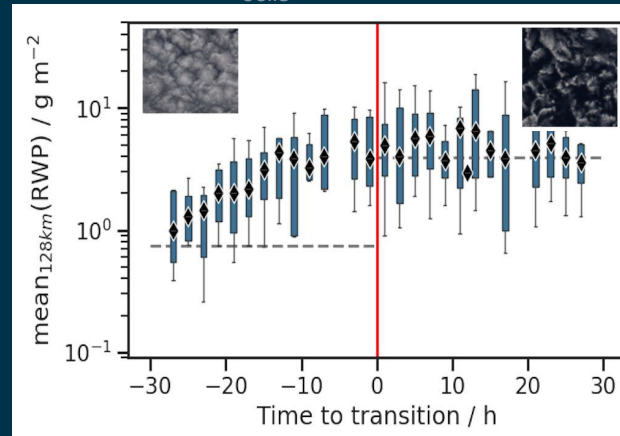
Lightning prediction

Blanka Piskala Gvozdkova¹



Cloud structure detection

Johanna Mayer¹
closed cells open cells

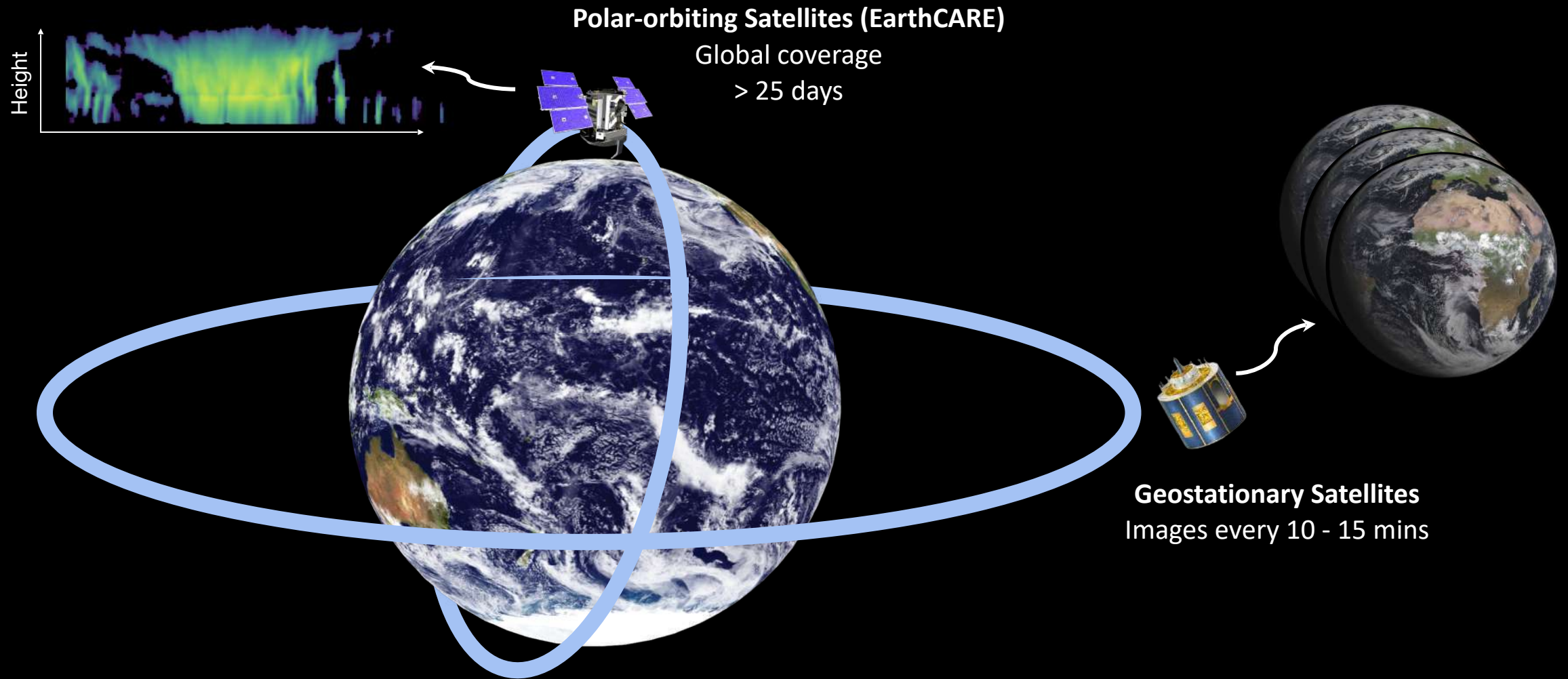


3D cloud reconstruction

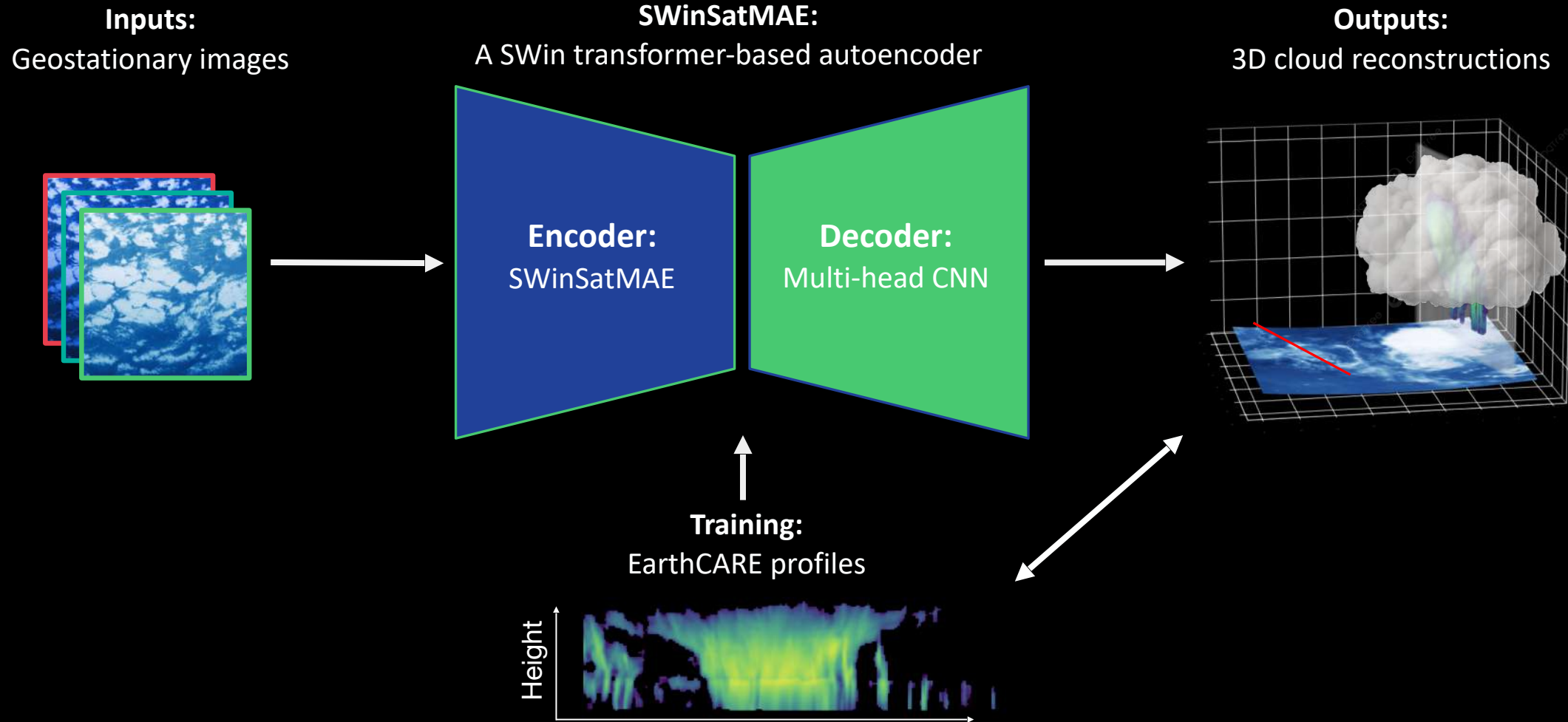


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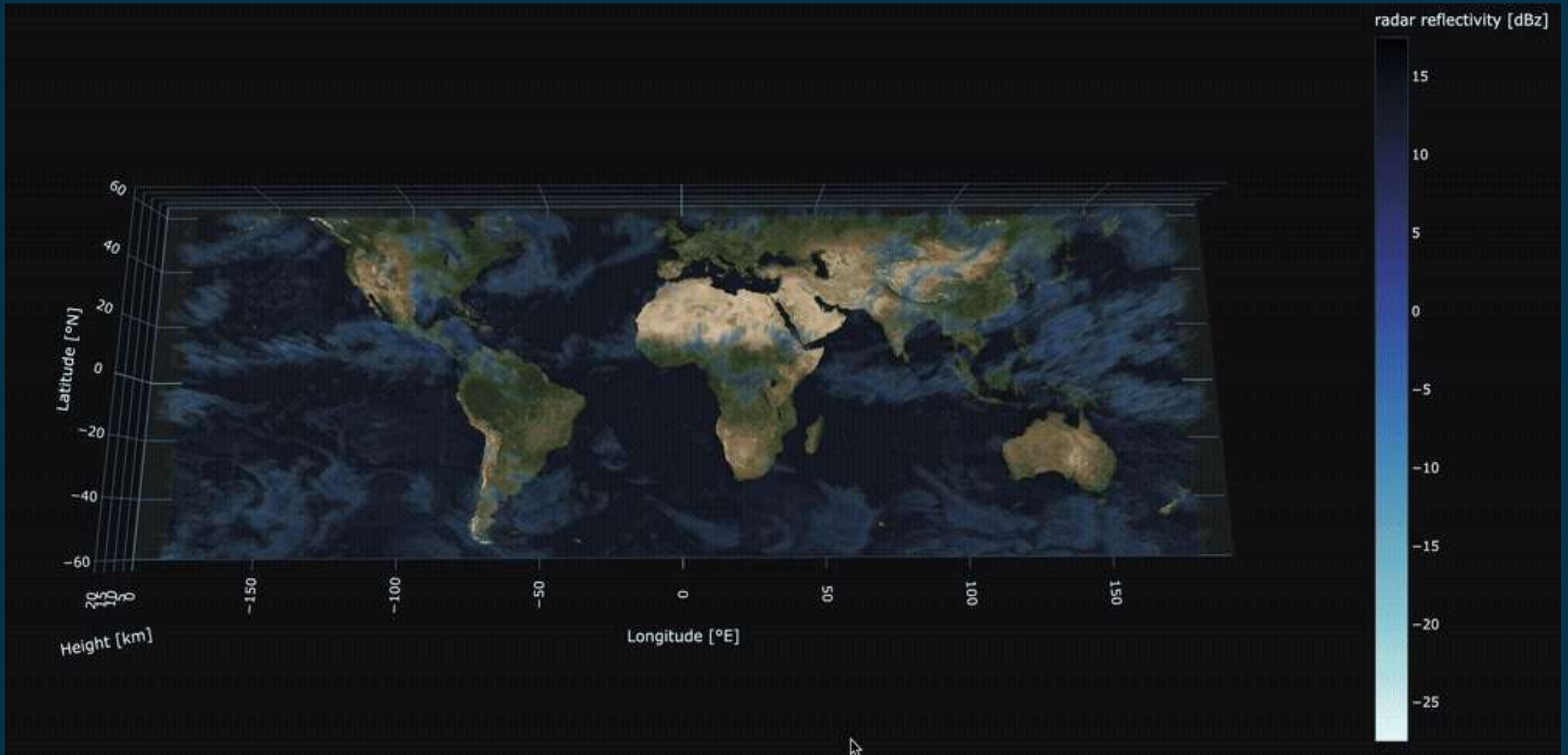
EarthCARE and geostationary satellites have complementary strengths



AI methods to learn cloud vertical profiles



Global 3D reconstruction of clouds



3D structure helps to better predict extreme events

Hurricane Dorian 2019-08-31 12:05

Geostationary images

Model slice through storm

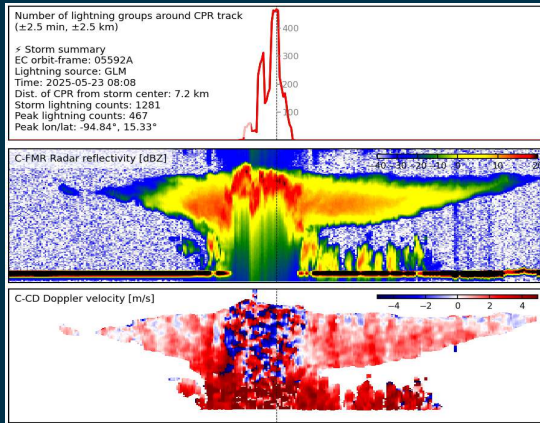
Maximum column radar
reflectivity from model



EarthCARE + AI methods

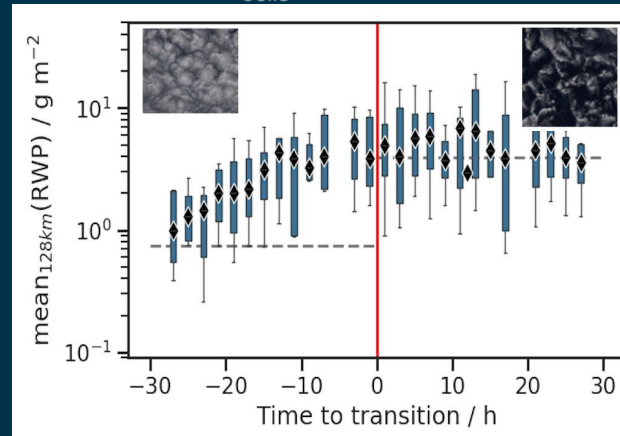
Lightning prediction

Blanka Piskala Gvozdkova¹



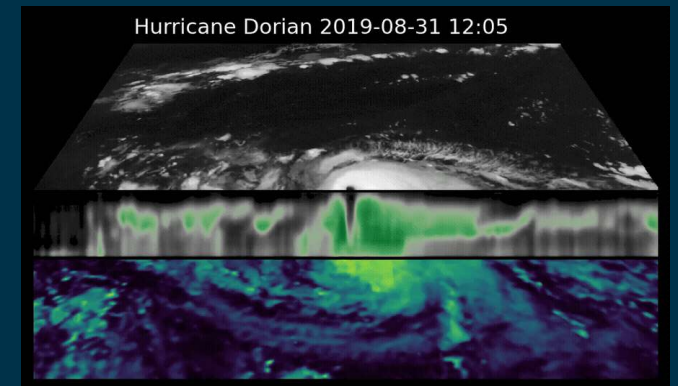
Cloud structure detection

Johanna Mayer¹
closed cells open cells



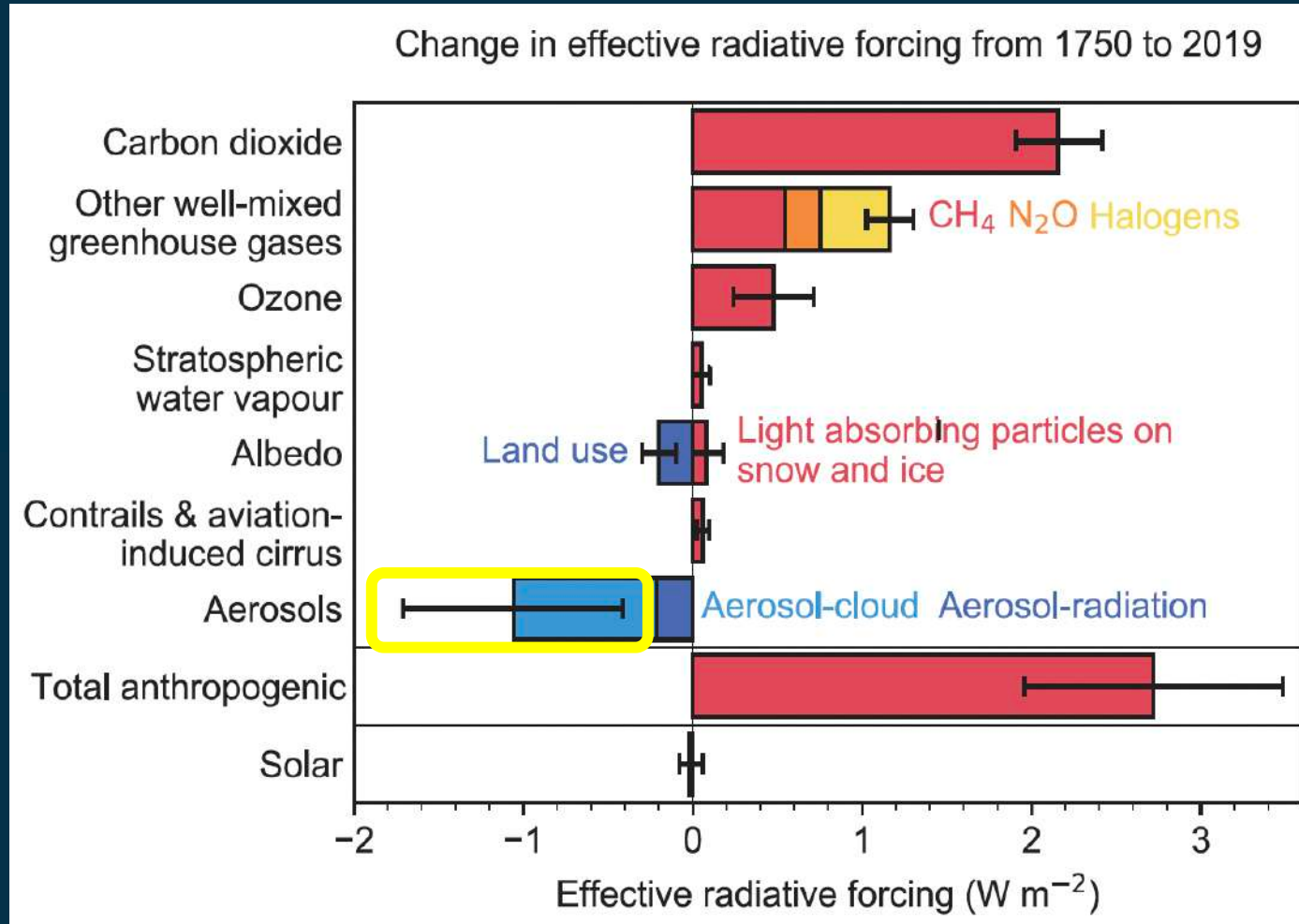
3D cloud reconstruction

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- EarthCARE can provide unprecedented measurements of aerosols and clouds
- AI methods are a powerful tool to make best use of the data, e.g. by...
 - detecting patterns in the data to help us understand complex processes (lightning)
 - classifying tasks which are difficult with traditional methods (cloud structure)
 - expanding and extrapolating observations (3D reconstruction)
- Overall goal: improve weather and climate predictions

Aerosol cloud interactions constitute the largest uncertainty in radiative forcing estimates



IPCC, AR6/WG1, 2021

EarthCARE + AI methods

Lightning prediction

Blanka Piskala Gvozdkova¹

- Improve understanding of lightning and its parameterizations in weather models

Cloud structure detection

Johanna Mayer¹

- Insights into cloud processes
- Improve physical understanding of cloud climate feedbacks

3D cloud reconstruction



- Shirin Ermis⁷, Cesar Aybar², Lilli Freischem⁷, Stella Girtsou^{3,4}, Kyriaki-Margarita Bintsi^{5,6}, Emiliano Diaz Salas-Porras², Michael Eisinger¹, William Jones⁷, Anna Jungbluth¹, Benoit Tremblay⁸
- Knowledge of cloud 3D structure is key to know how storms are evolving
 - better predict extreme events.