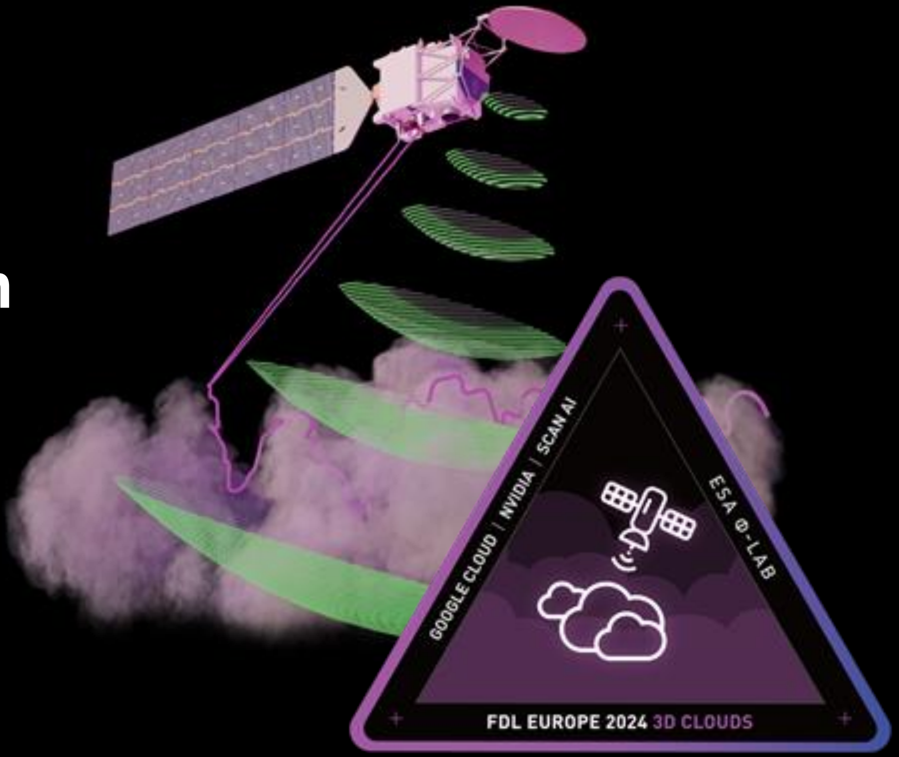
TRILLIUM EUROPE

EARTH SYSTEMS LAB

Deriving 3D Cloud Maps from 2D Satellite Imagery using Machine Learning



Anna Jungbluth & William Jones

17 October 2024

3D CLOUDS USING MULTI-SENISNG . 2024

esa Φ-lab
FDL 2024 EUROPE
EARTH SYSTEMS LAB

RESEARCHERS


Stella Girtsou


Lilli Freischem


Emiliano Díaz


Joppe Massant

FACULTY


Giuseppe Castiglione


William Jones

FACULTY


Margarita Bintsi

ADVISOR


Anna Jungbluth

ADVISOR

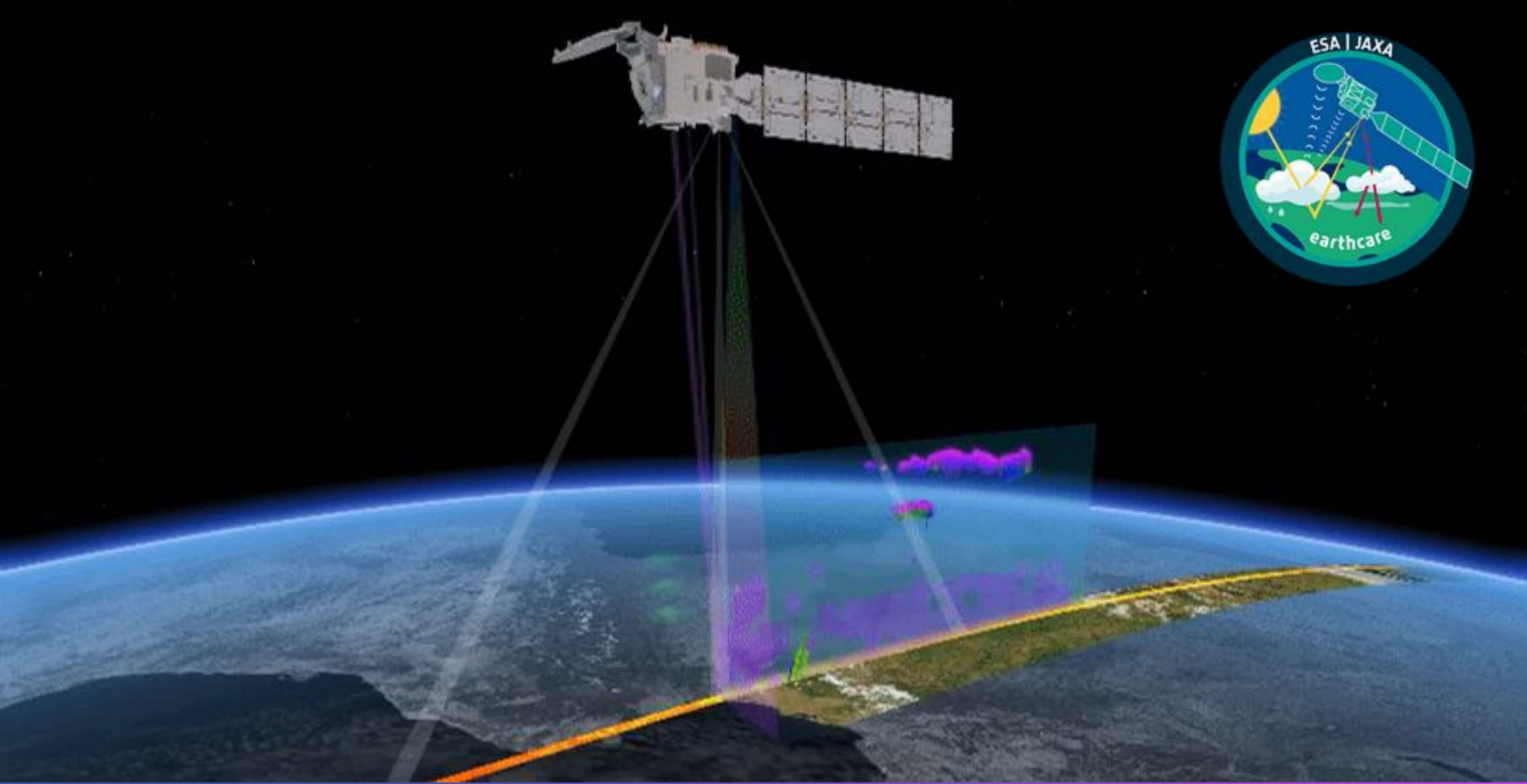

J. Emmanuel Johnson

ADVISOR


Michael Eisinger

nge is “a distant problem that requires sacrifices now to avoid uncertain losses far in the future”

- Daniel Kahneman



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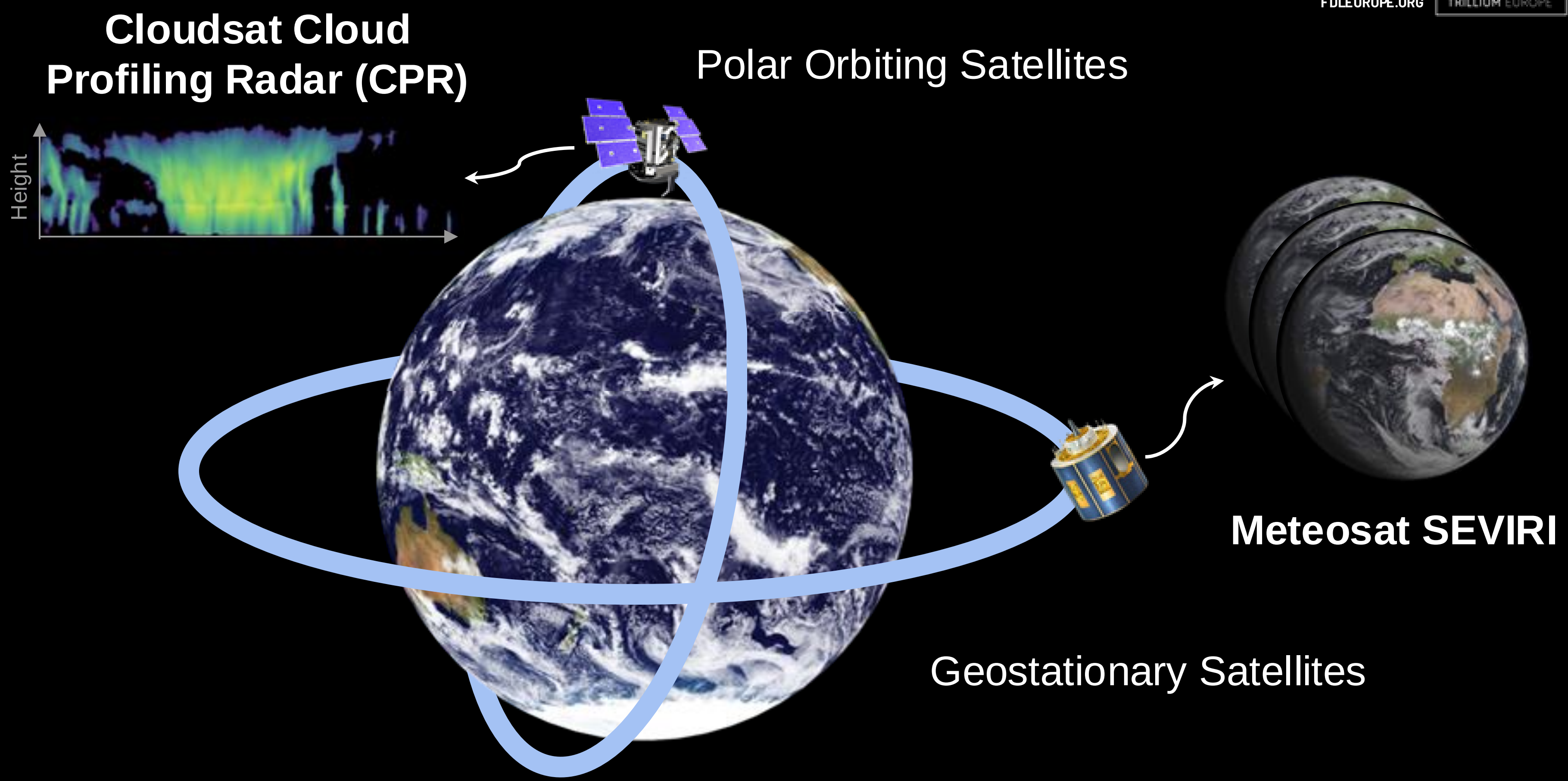
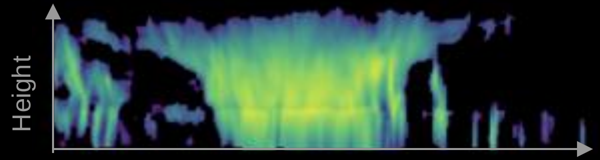
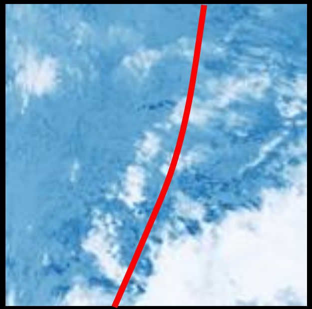

Cloudsat Cloud Profiling Radar (CPR)
Height
Polar Orbiting Satellites
Meteosat SEVIRI
Geostationary Satellites

SEVIRI
multi-channel imagery

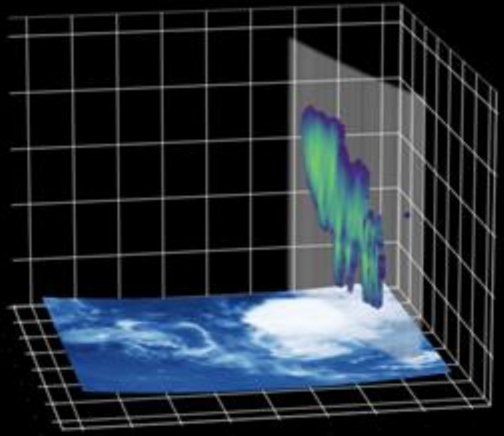


CPR radar profiles

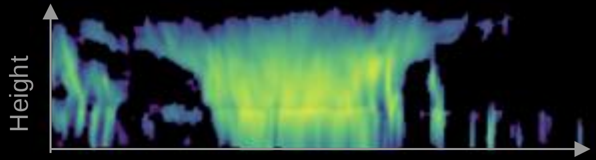
Align in space
and time

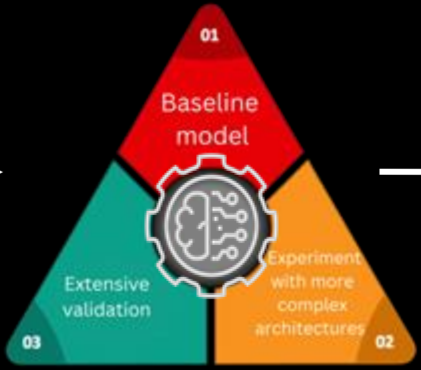


Transform to
3D cube



Paired observations

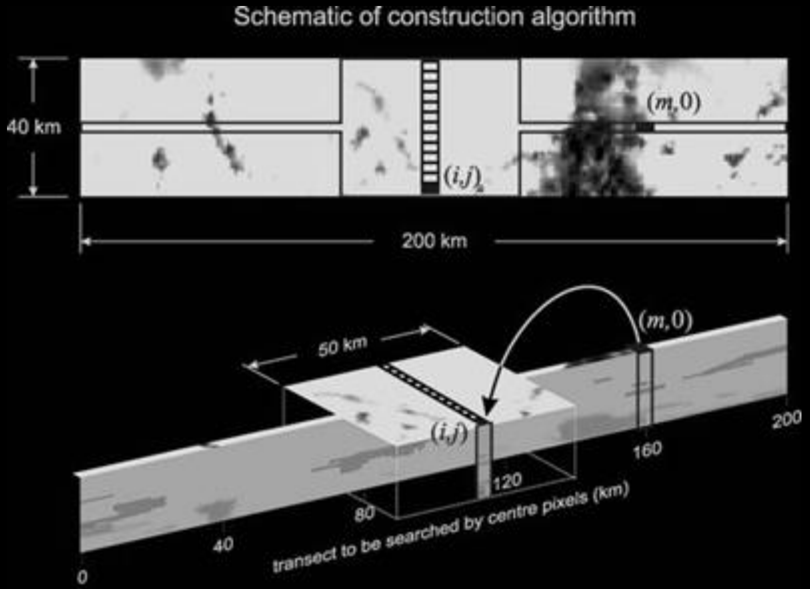




3D cloud maps

State-of-the-art approaches

EarthCARE across-track reconstruction
Pattern matching



Barker et al., “A 3D cloud-construction algorithm for the EarthCARE satellite mission”, *QJRMS* 2011

State-of-the-art approaches

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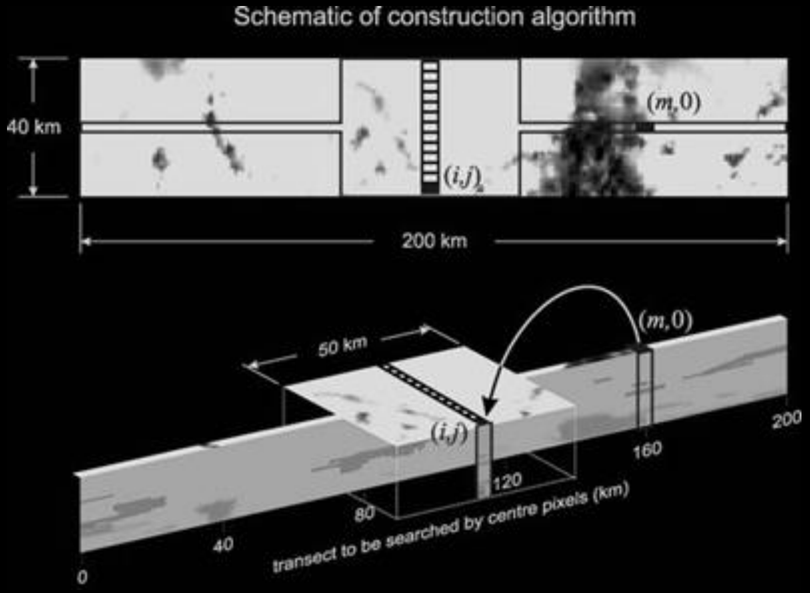
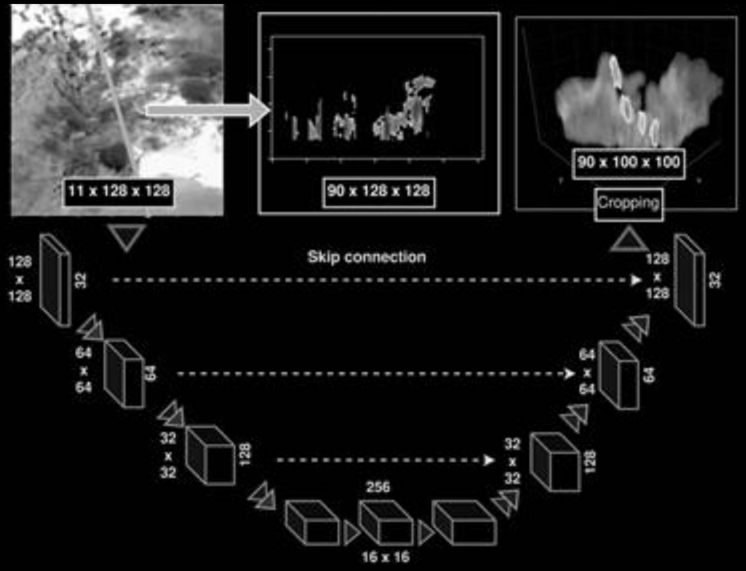
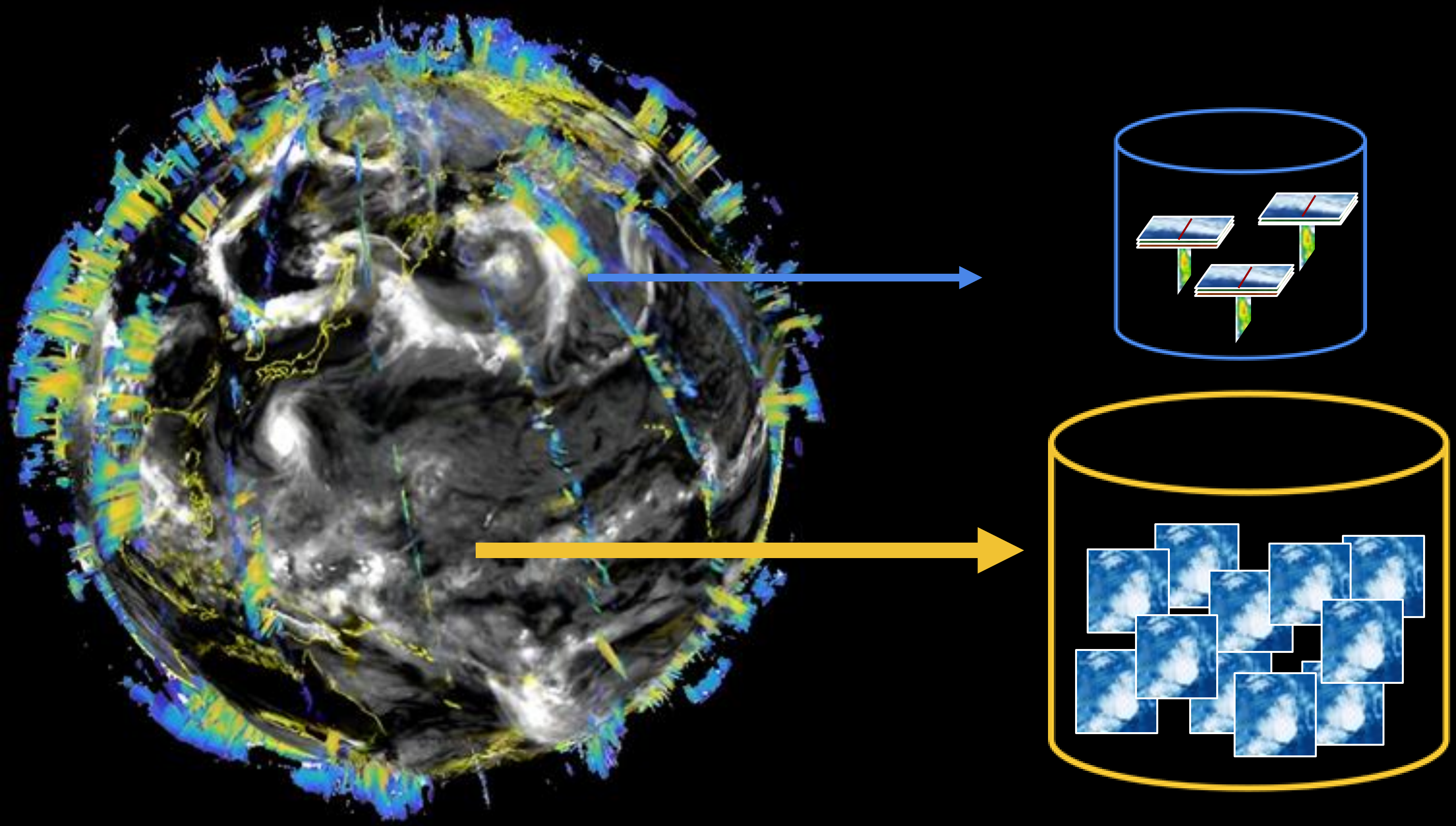


Barker et al., “A 3D cloud-construction algorithm for the EarthCARE satellite mission”, *QJRMS* 2011

U-Net 3D reconstruction
Image-to-image translation



Brüning et al., “Artificial intelligence (AI)-derived 3D cloud tomography from geostationary 2D satellite data”, *AMT* 2024.



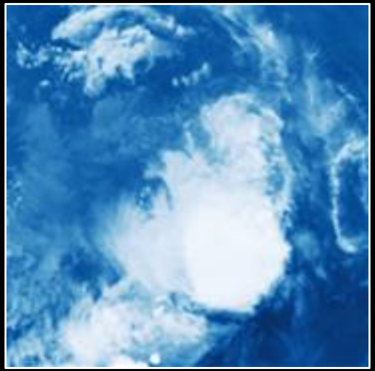
Gigabytes of
Image-Profile Pairs

Terabytes of
Unpaired Images

Our Approach

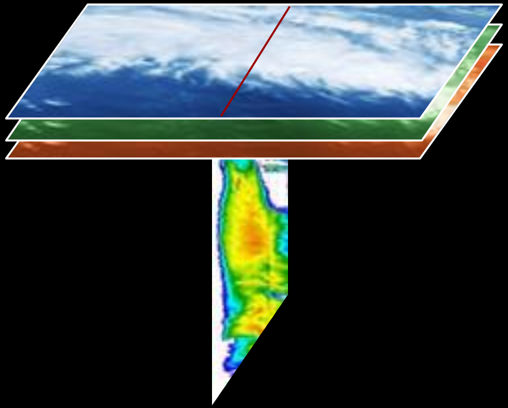
Step 1:
Learn from terabytes of unpaired images

Via **Self-Supervised Learning**

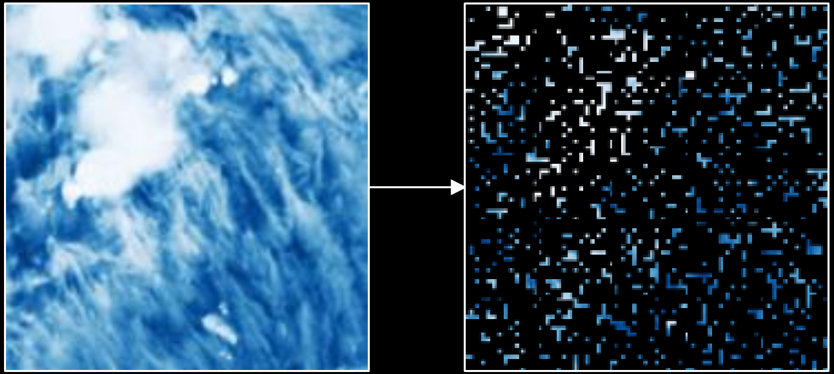


Step 2:
Specialize to predict 3D from image-profile pairs

Via **Supervised Learning**



Step 1: Learn from TBs of unpaired images via **self-supervised learning**

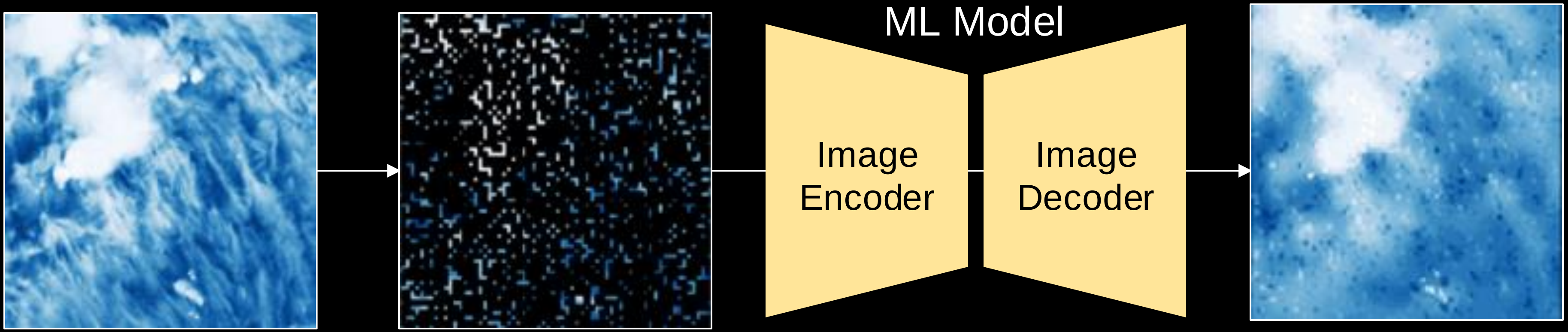


Goal:
Learn underlying features in satellite data!

Masked Autoencoders (MAEs)

Credit: He et al. Masked Autoencoders Are Scalable Vision Learners, arXiv:2111.06377

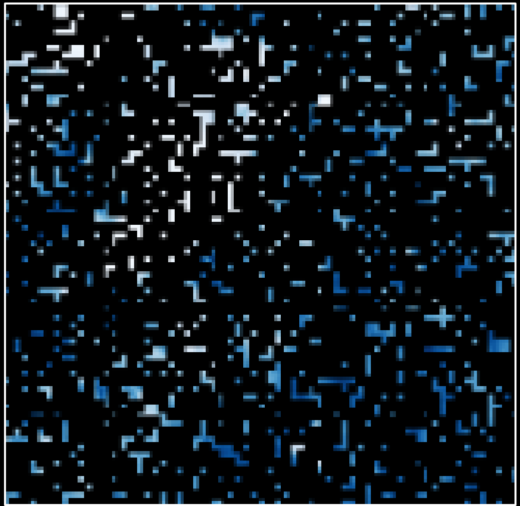
Step 1: Learn from TBs of unpaired images via **self-supervised learning**



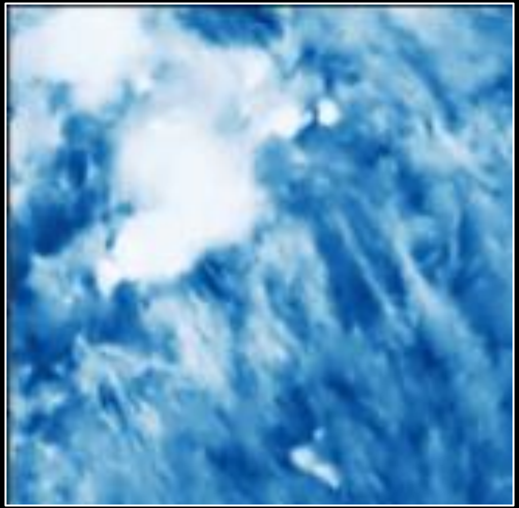
Masked Autoencoders (MAEs)

Credit: He et al. Masked Autoencoders Are Scalable Vision Learners, arXiv:2111.06377

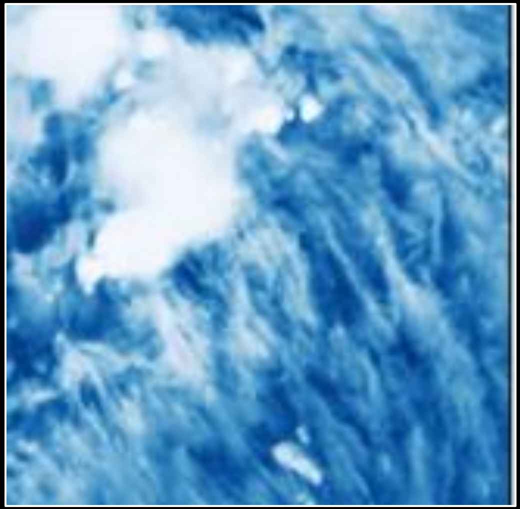
Masked



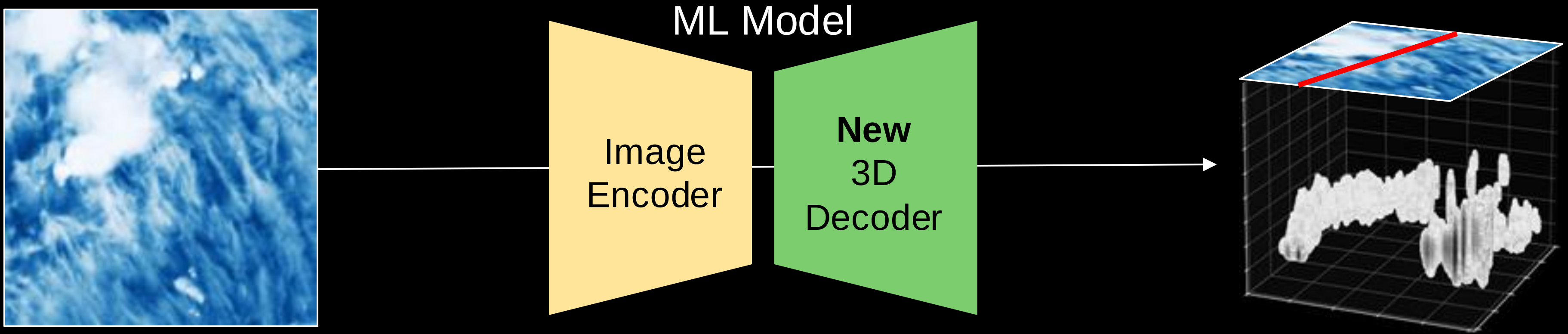
Reconstructed



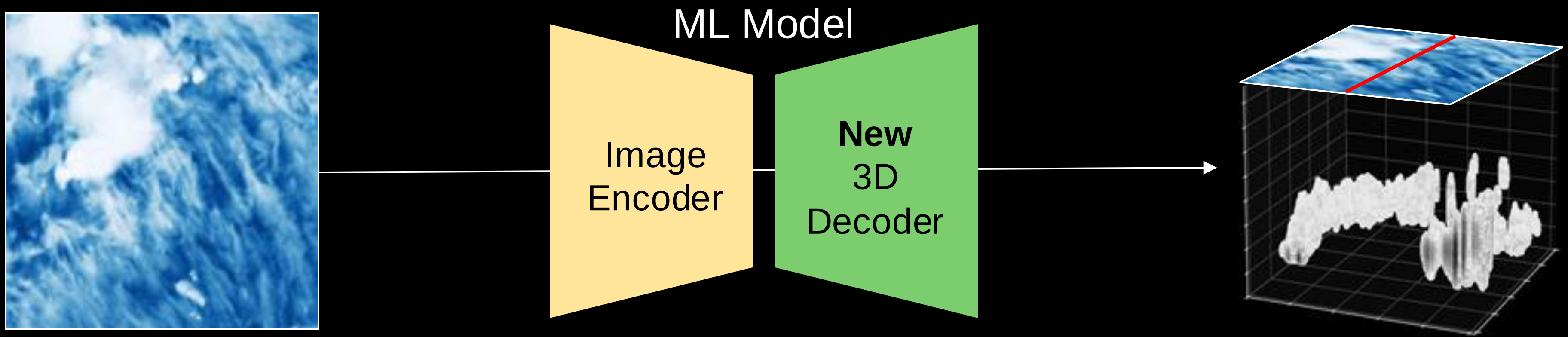
Original



Step 2: Specialize to predict 3D from image-profile pairs via **supervised learning**



Step 2: Specialize to predict 3D from image-profile pairs via **supervised learning**

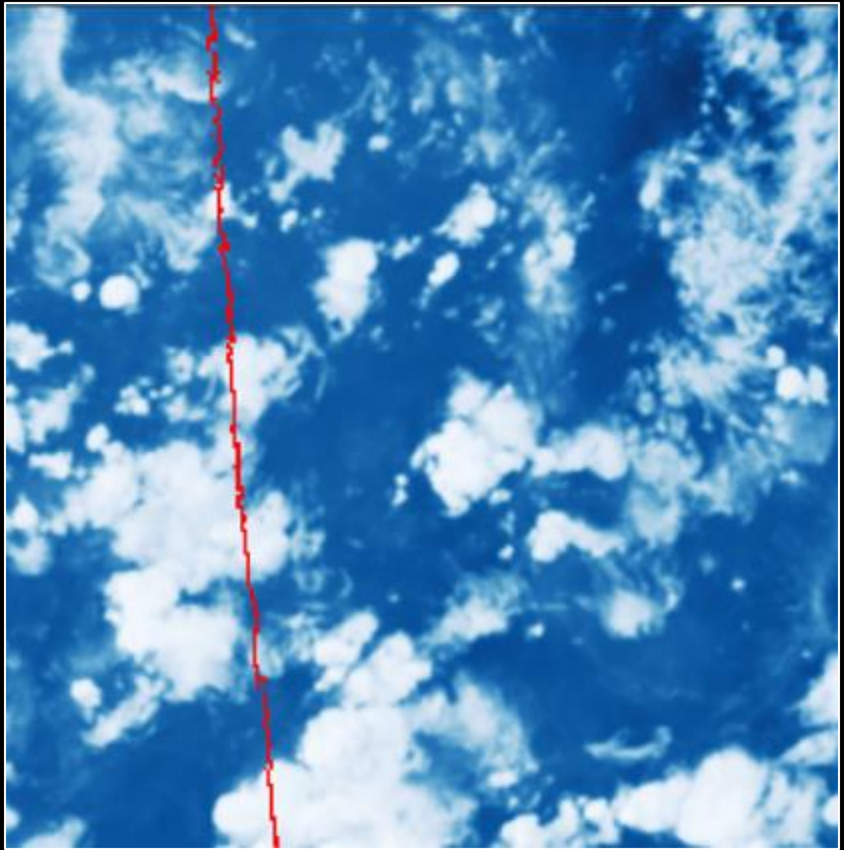


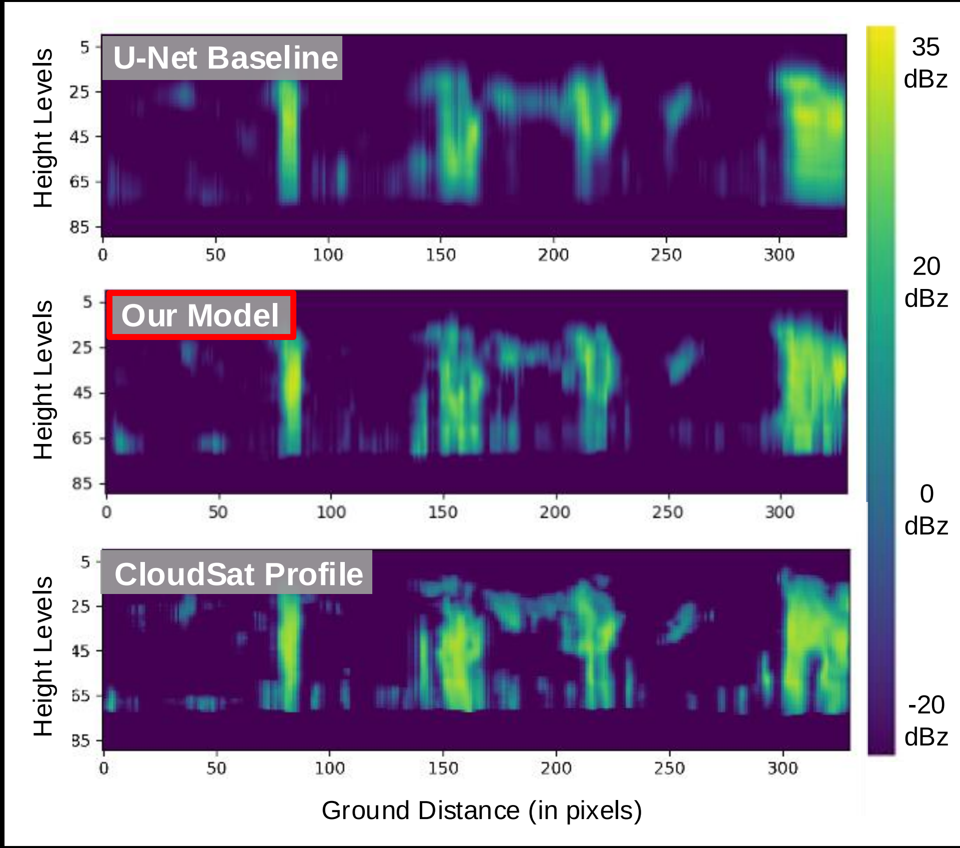
“Geospatially-aware” ML model

→ Encode time (YYYYMMDD HHMMSS)

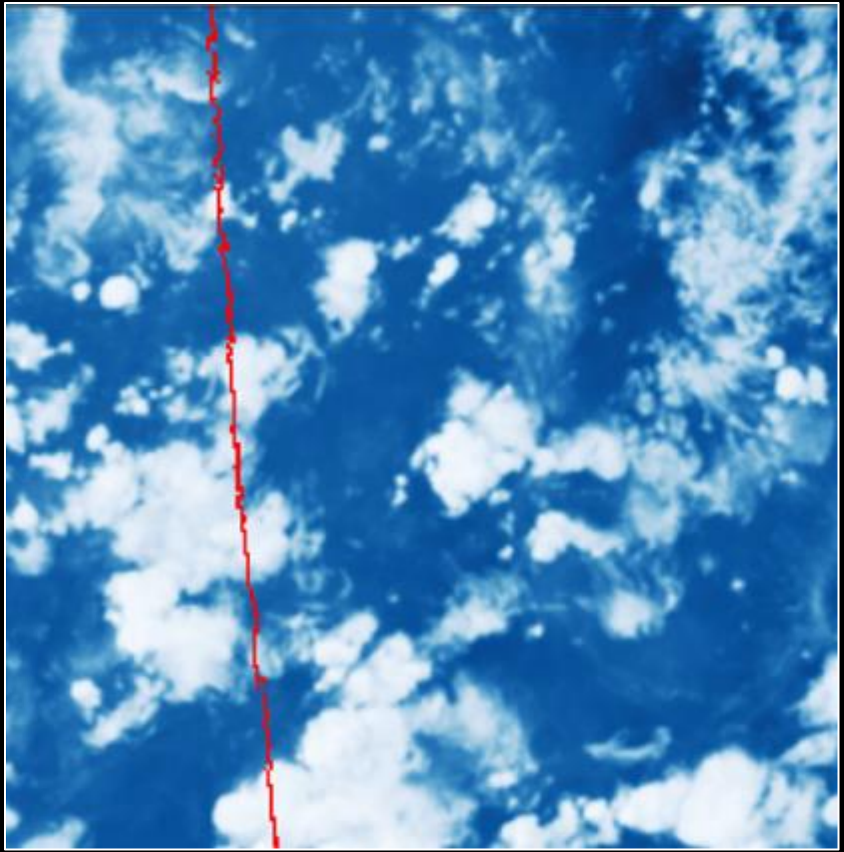
→ Encode location (Latitude & Longitude)

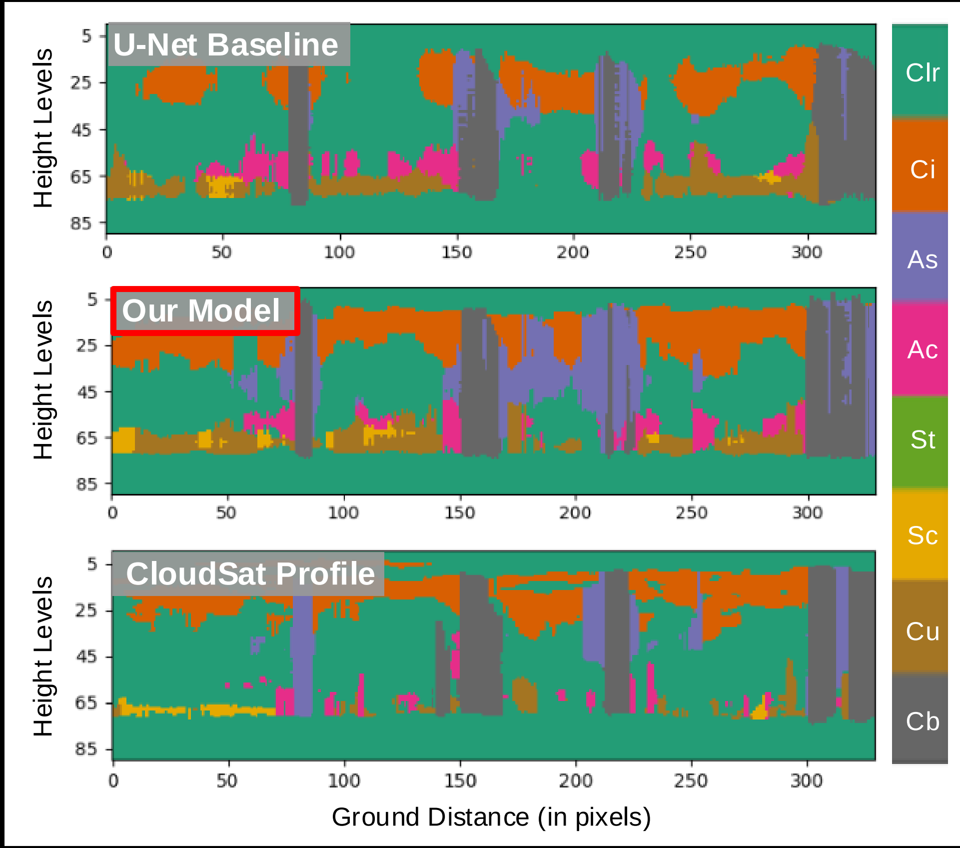
Prediction Results



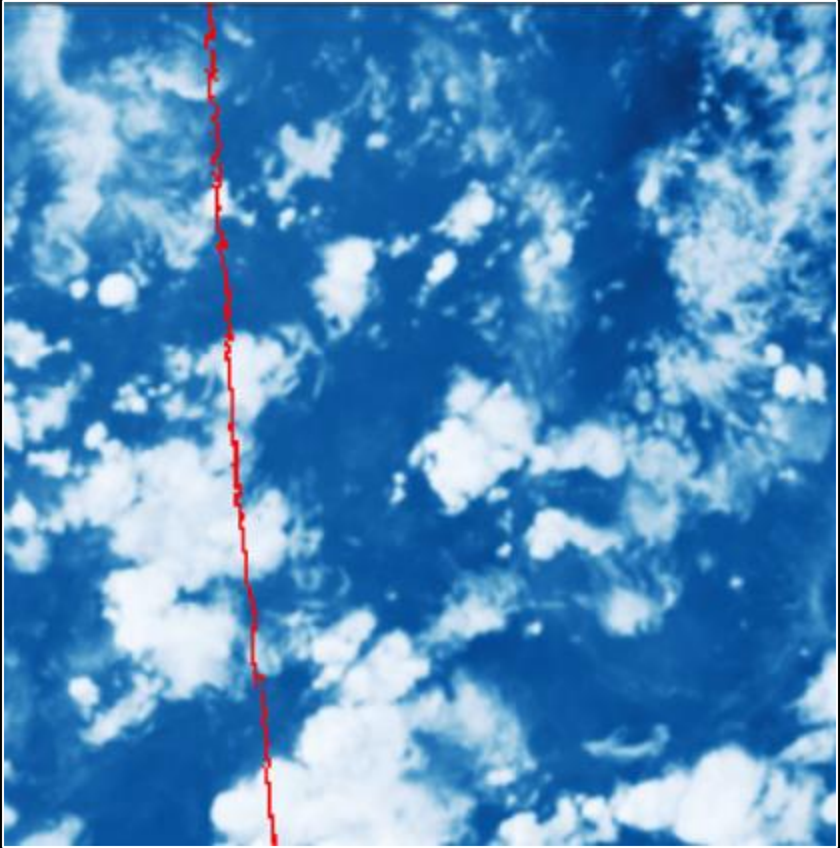


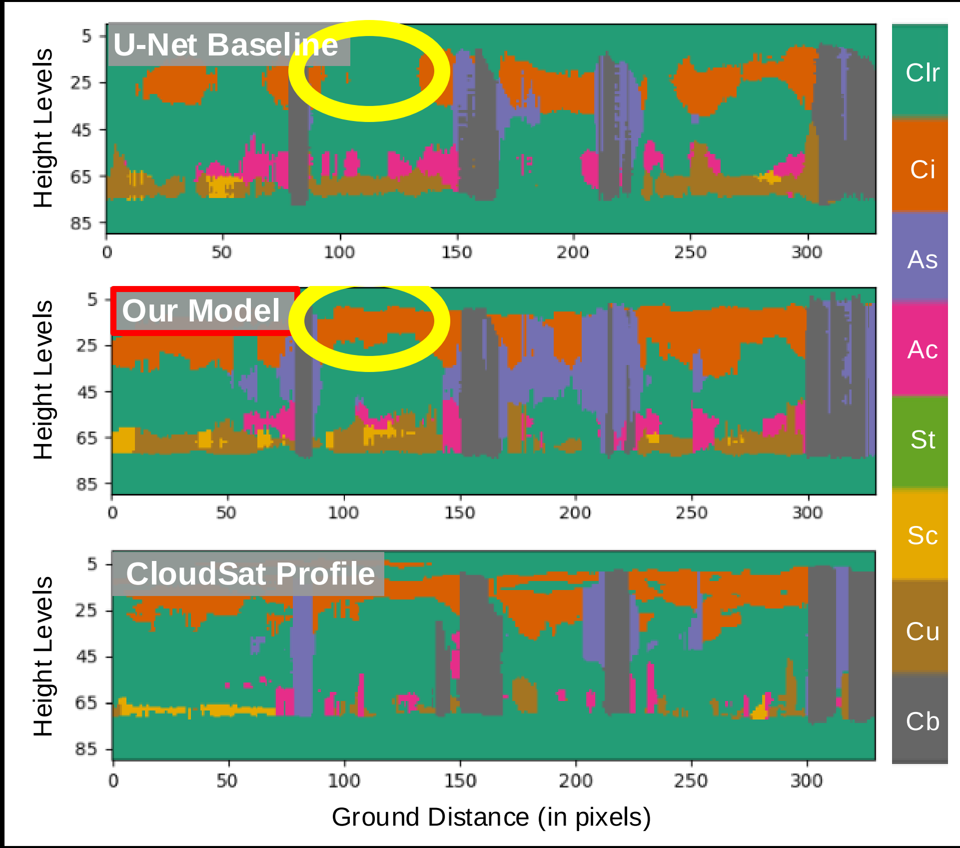
Prediction Results



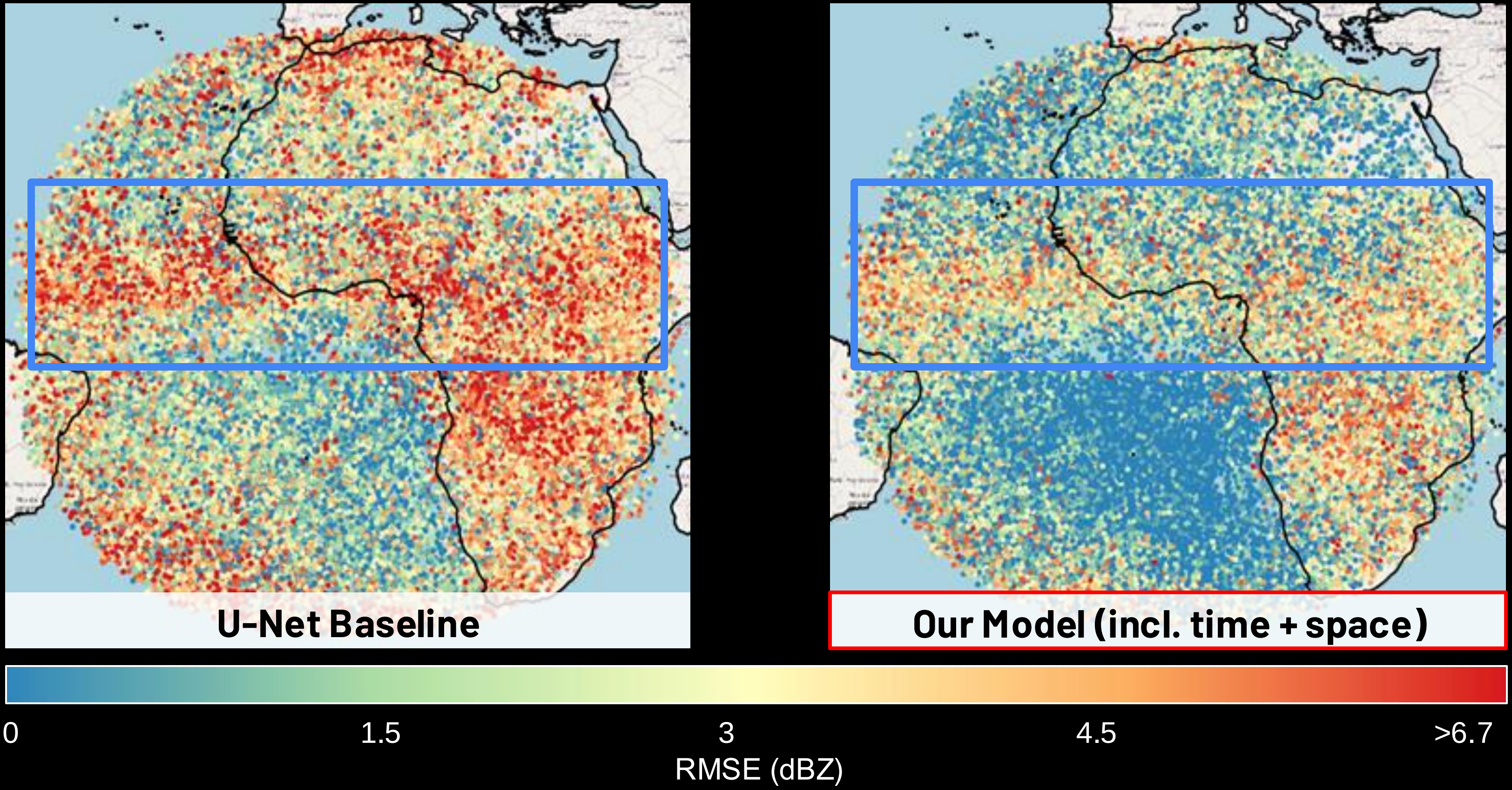


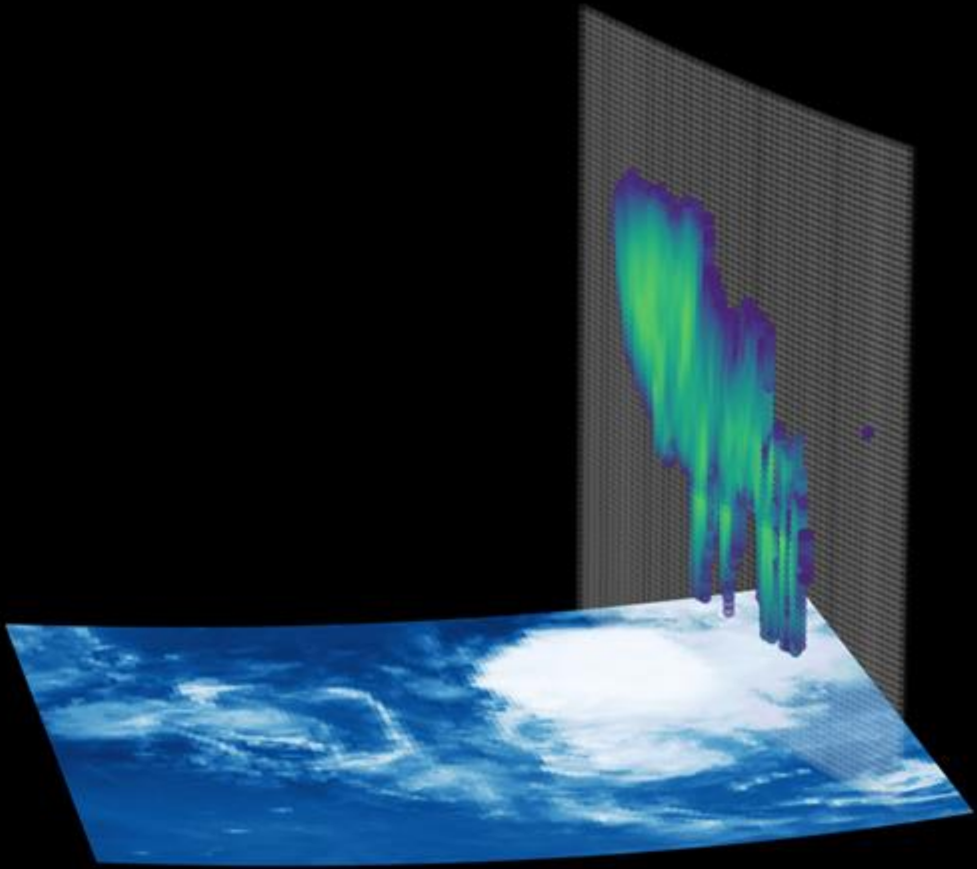
Prediction Results

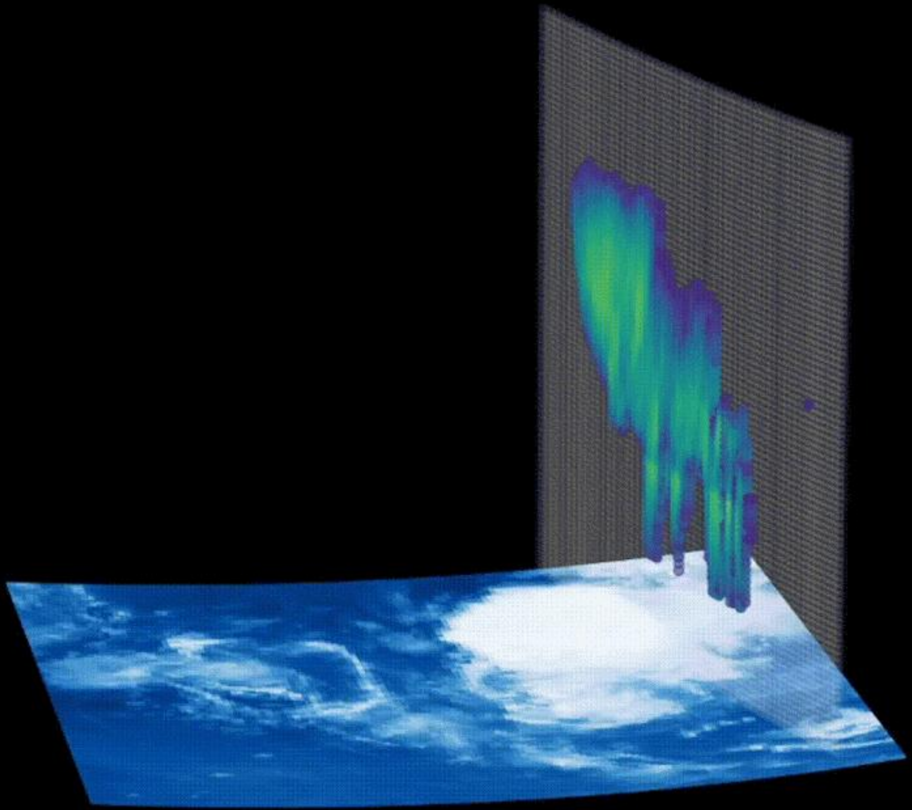


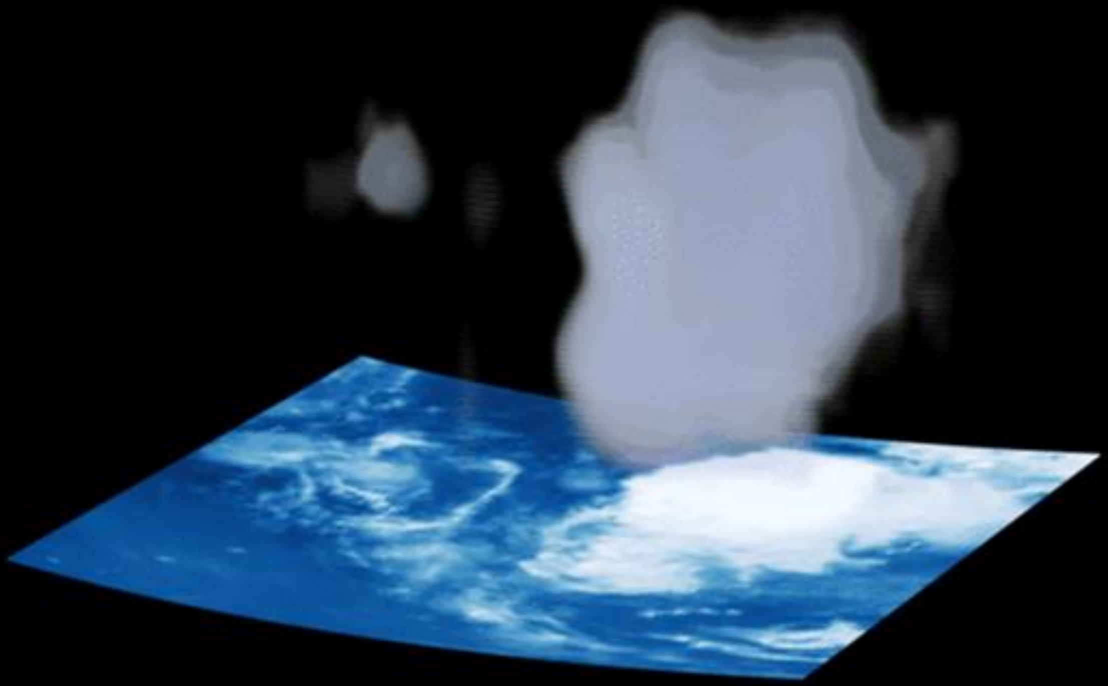


Reduced Regional Bias with Geospatial ML Model









Thank You!