Global Identification of Convective Cores from EarthCARE Doppler Velocity Observations

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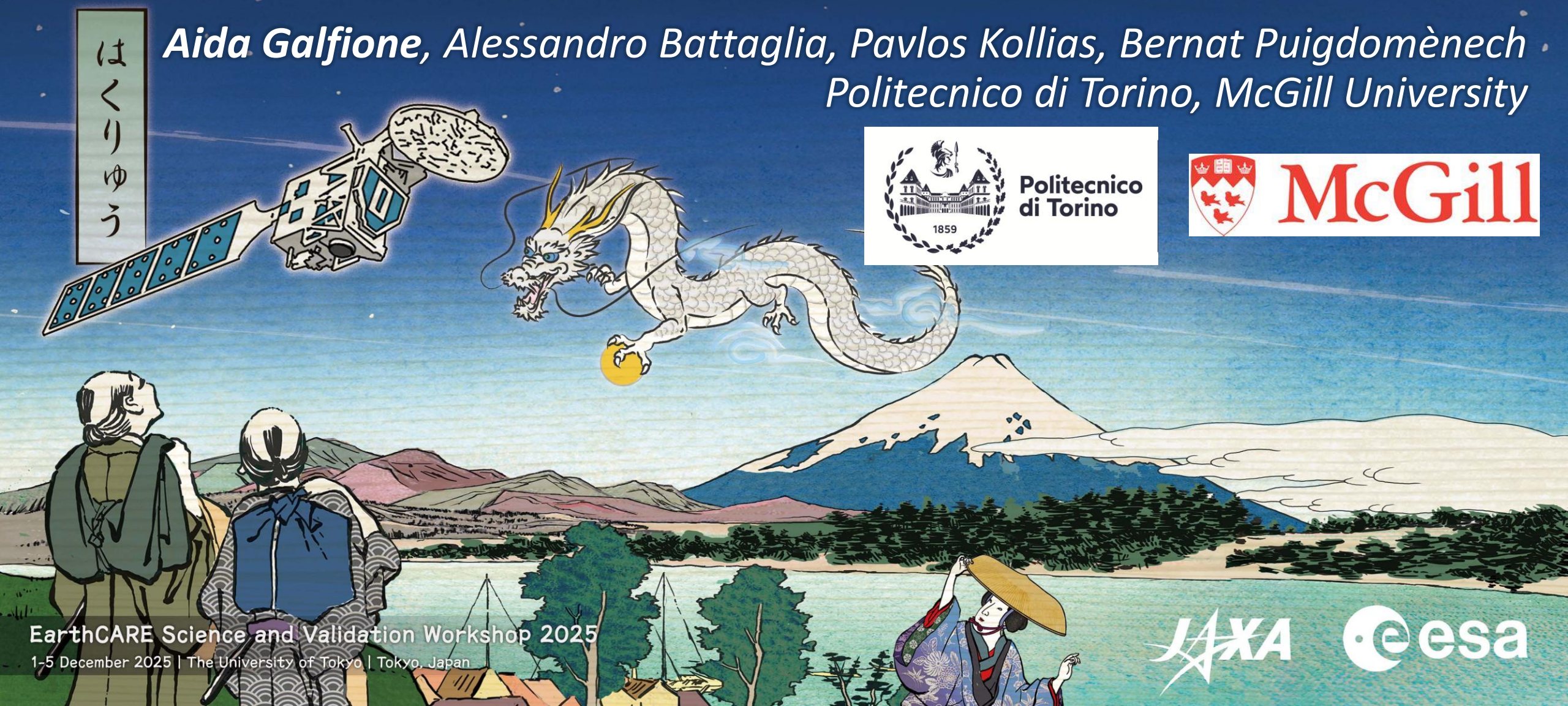

EarthCARE Science and Validation Workshop 2025
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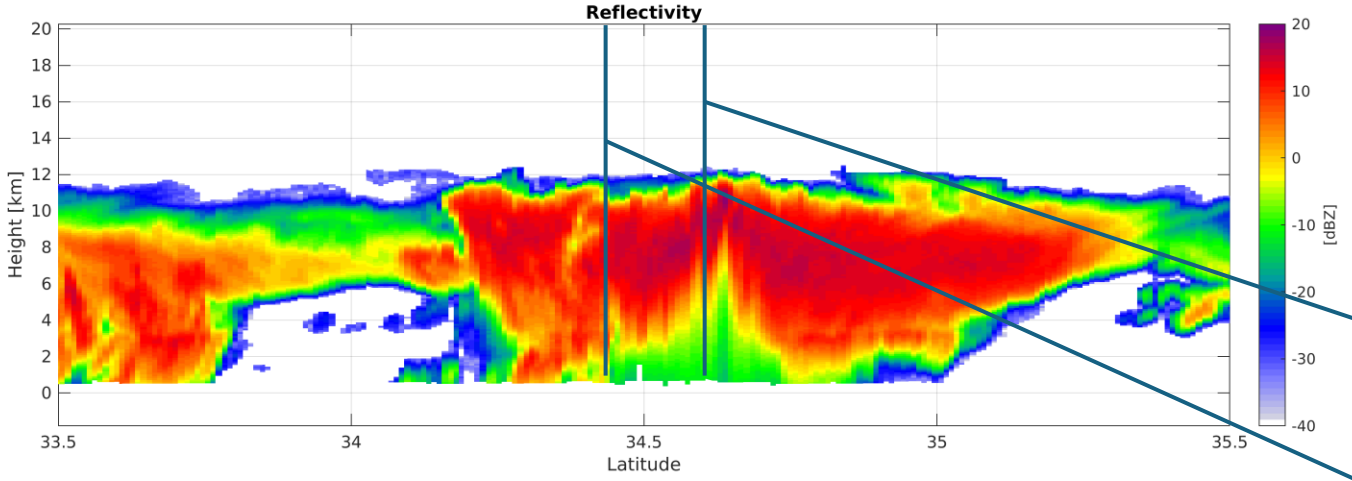
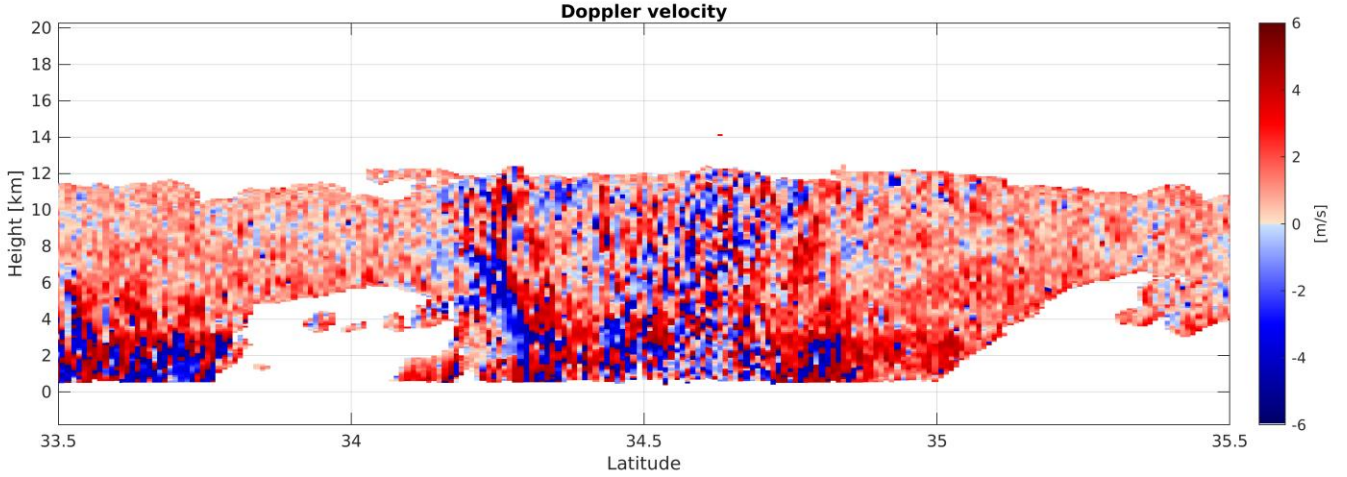
The challenges of EC-CPR measurements in deep convective cores

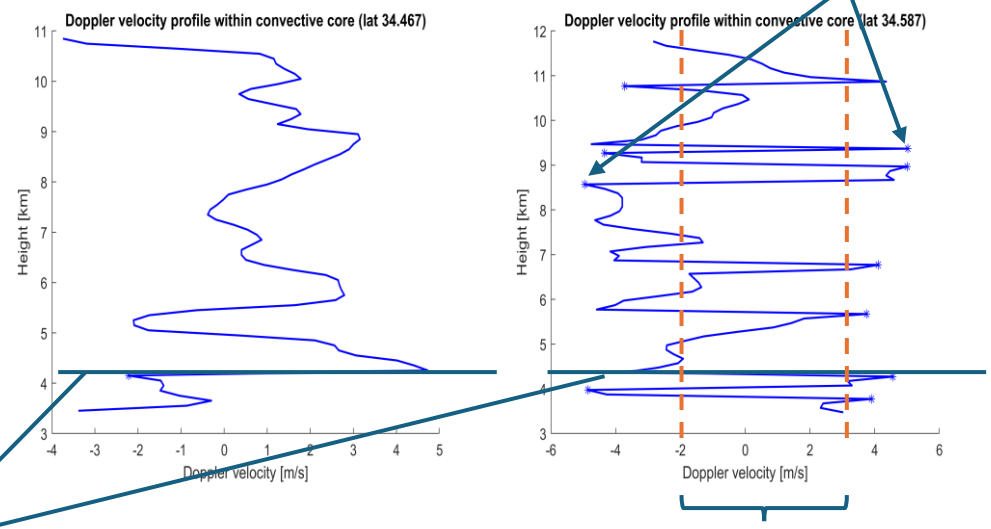




frame 2234D, 19/10/2024, 13:19 UTC,
South Mediterranean Sea

- **High variability in Doppler velocity**, often leading to **velocity aliasing (v_N≈5 m/s)** and values exceeding **the expected stratiform range of −2 to 3 m/s**.
- **Lack of reliable boundary conditions** ➔ Doppler velocity **unfolding highly challenging**, as multiple valid solutions may exist.

Folding



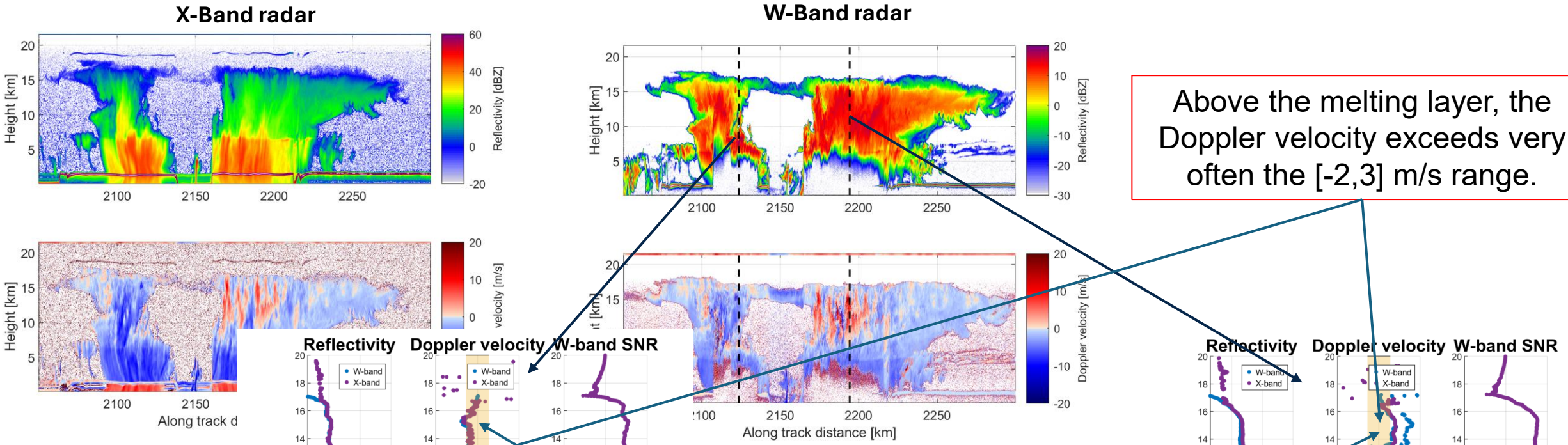
Melting layer height

Stratiform range

Aircraft data from ALOFT (2023) field campaign

NASA ALOFT field campaign data (Florida, July 2023; thunderstorm/lightning/gamma-rays flashes and glows) can be used as guidance to check criteria for EC convection classification (very large Nyquist, X-band reference)

X and W-band profiles over a **deep stratiform event, with embedded convection**

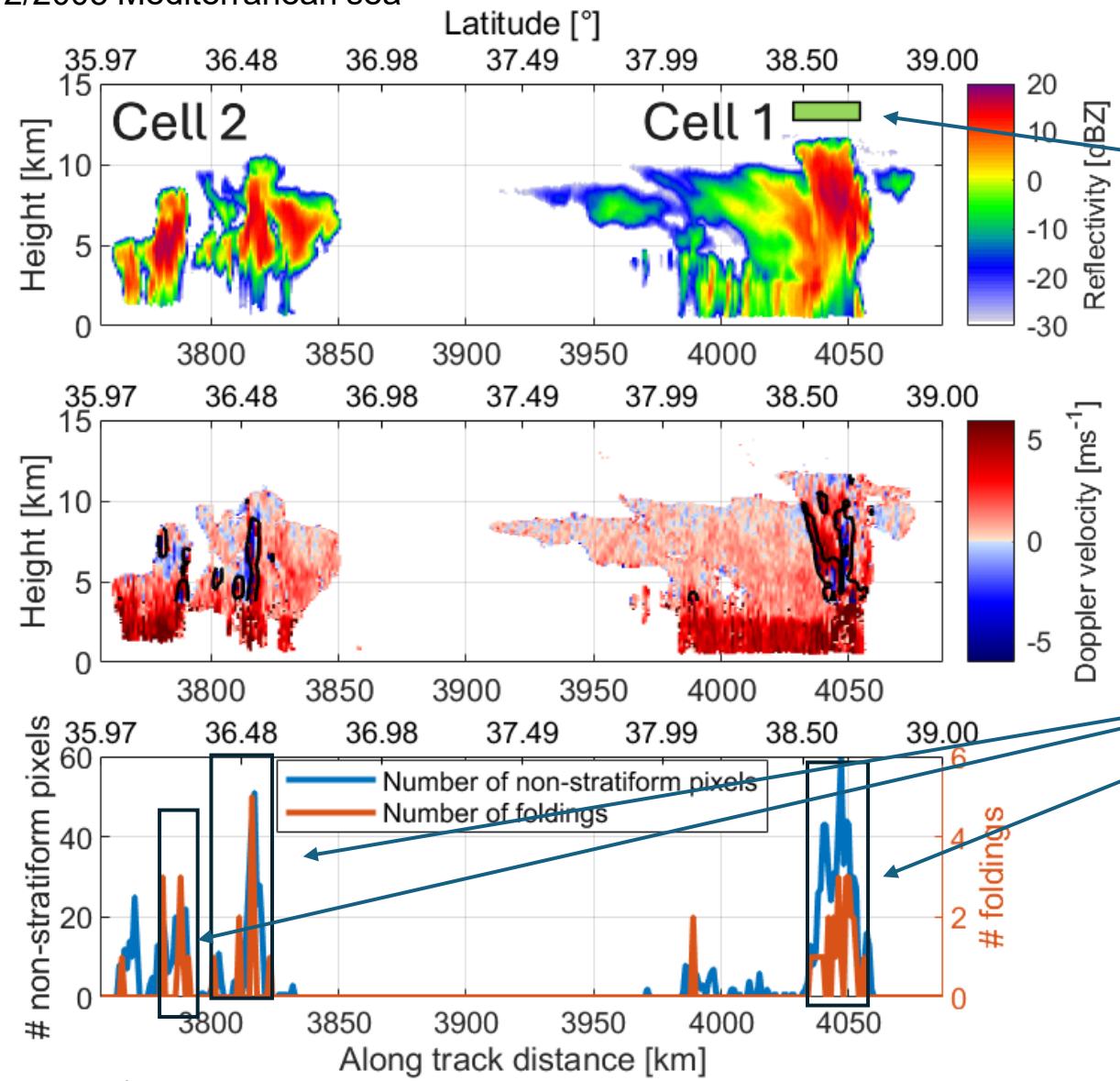


Above the melting layer, the Doppler velocity exceeds very often the [-2,3] m/s range.

For EC-CPR it is very likely that the Doppler velocity above the melting layer is outside the yellow shading (±5 m/s)➔ aliasing

Identification of convective profiles: morphological vs dynamic criteria

7/12/2005 Mediterranean sea



Galfione et al., AMT 2025

Morphological criteria

Takahashi et al. 2014: based on reflectivity features:

- Continuous echo profile 2-10 km above surface
- 10 dBZ level above 10 km

Dynamic criteria (under assessment)

based on EarthCARE CPR Doppler velocity:

- **# Doppler velocity foldings** in ice
- **# Doppler velocities exceeding [-2,3] m/s in ice**

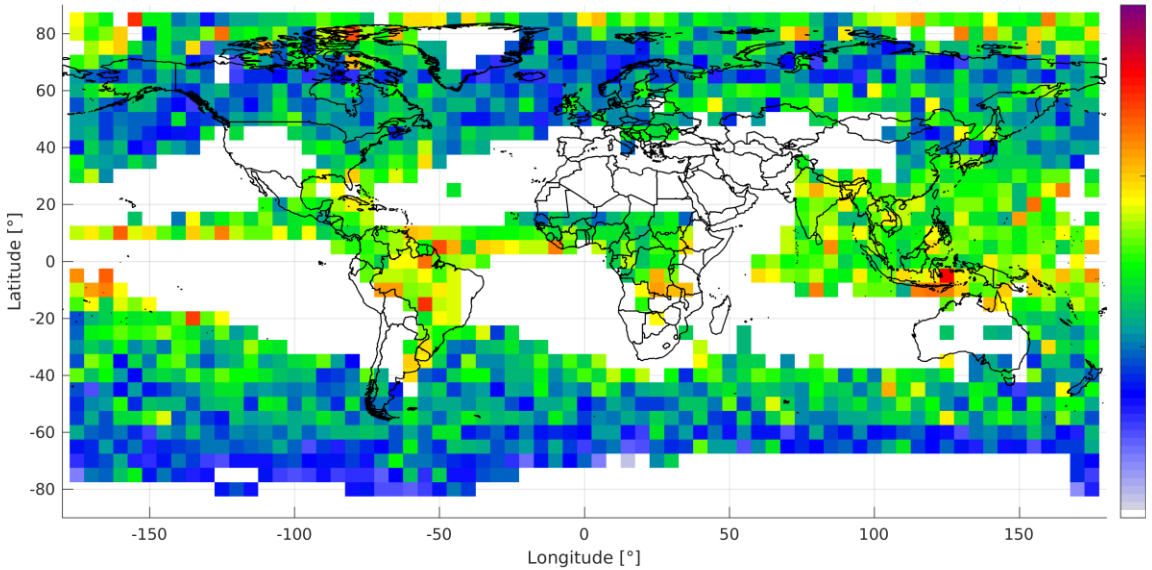
These two variables can be used as ***proxies of the convection strength***

How frequent are foldings?

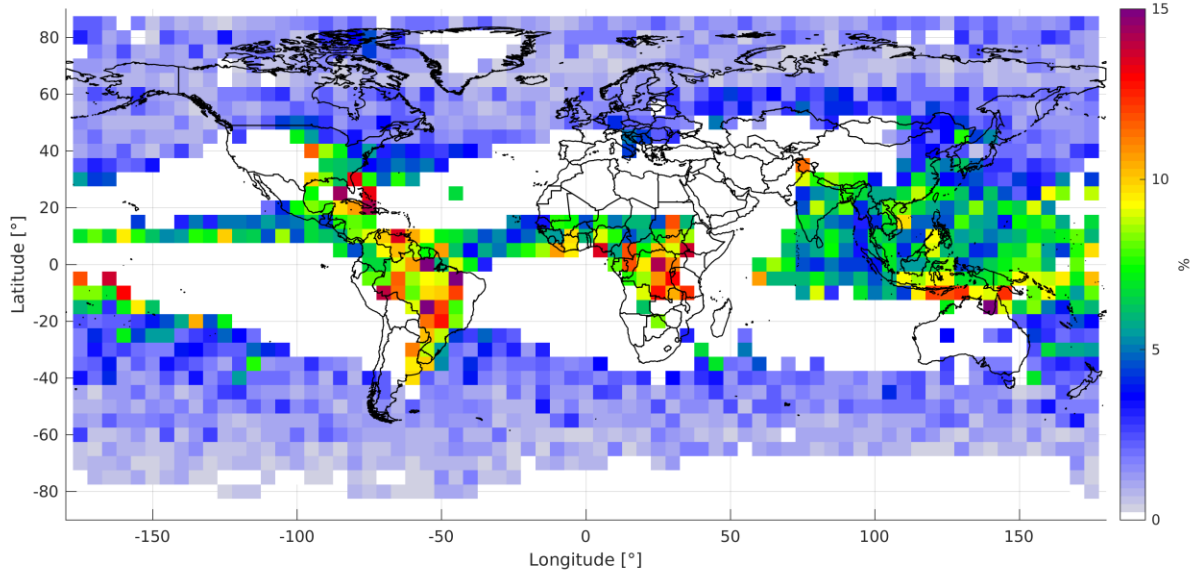
16 months of EarthCARE data

Fraction of profiles with N foldings/profiles with continuous echo between 2 and 8 km

with N=2 foldings



with N≥3 foldings



(Temptative) dynamic criteria for convection classification:

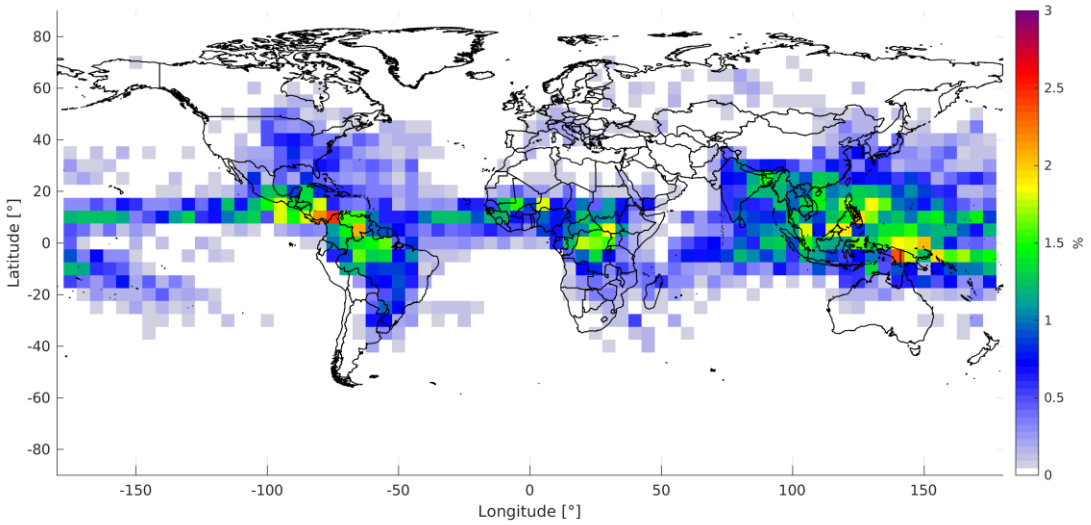
- **# Doppler velocity foldings in ice (i.e. 1 km above 0^0C isotherm) ≥2**
- **# Doppler velocities exceeding [-2,3] m/s in ice ≥ 10**

Global statistics of convective profiles

Morphological criteria

Takahashi et al. 2014: based on reflectivity features:

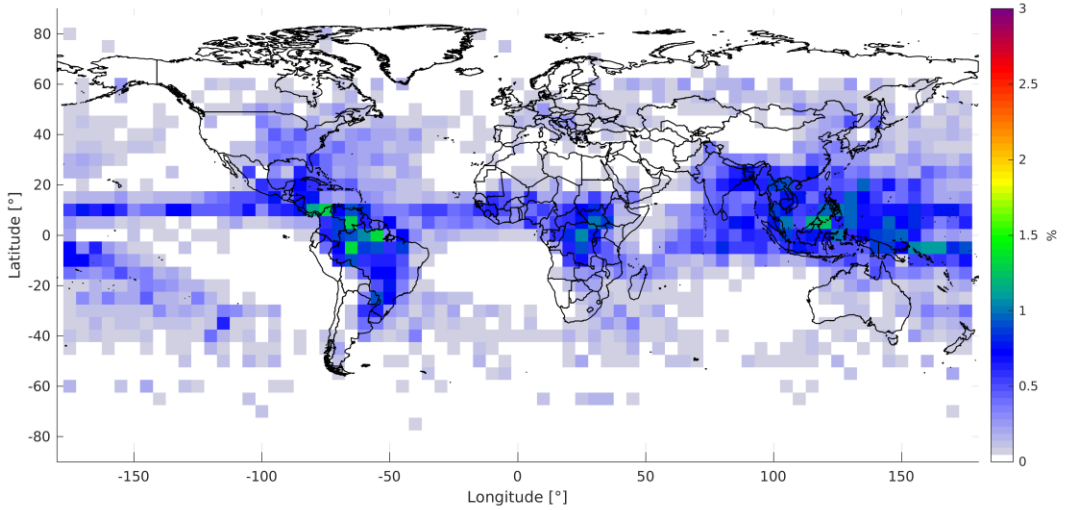
- Continuous echo profile 2-10 km above surface
- 10 dBZ level above 10 km



Dynamic criteria

based on EarthCARE CPR Doppler velocity:

- Continuous echo profile 2-8 km above surface
- Doppler velocity foldings in ice ≥2
- Doppler velocity pixels exceeding [-2,3] m/s in ice ≥10

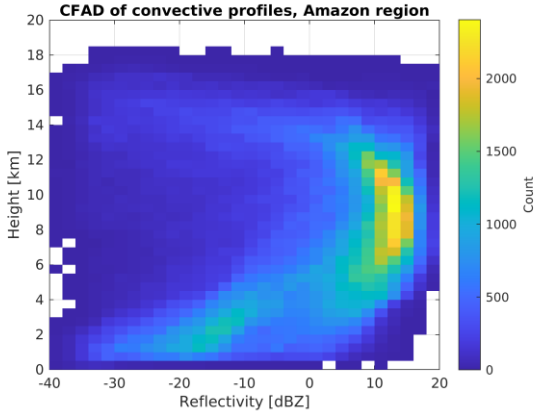


Percentage of convective profiles over the total number of profiles within a **5° x 5° grid** pixel

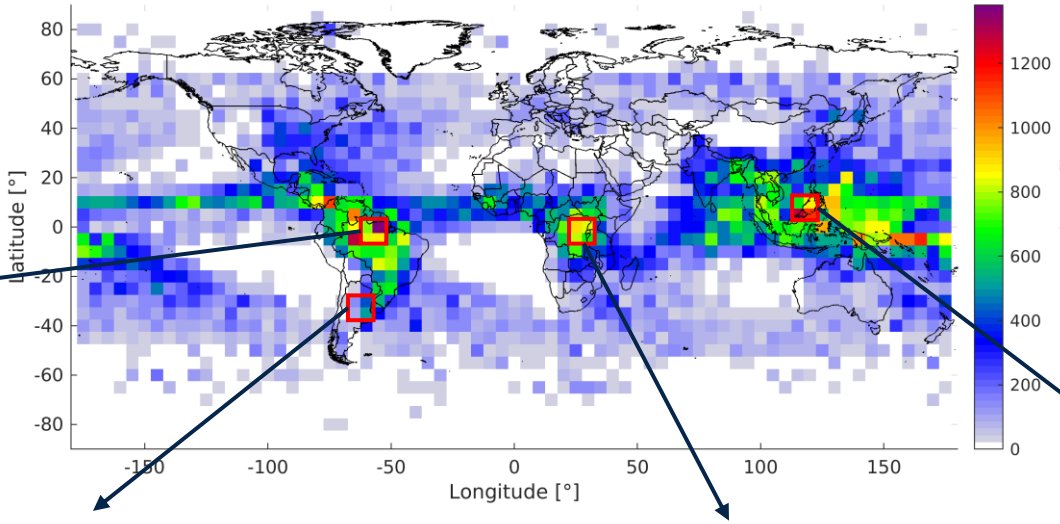
Vertical structure of convection: regional climatology

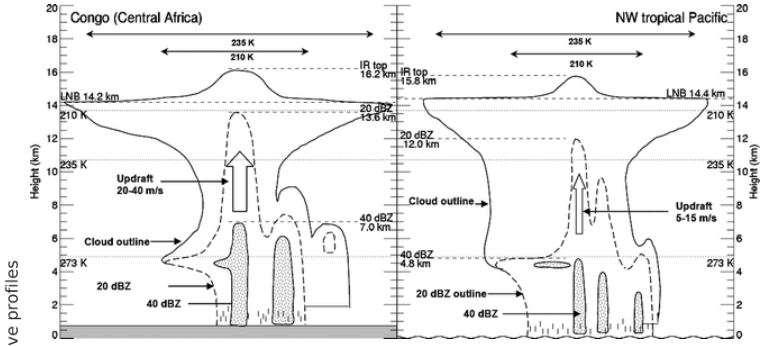
The classification of convective profiles based on the dynamic criteria can be used to characterise the different convective areas on Earth.

10° x 10° boxes

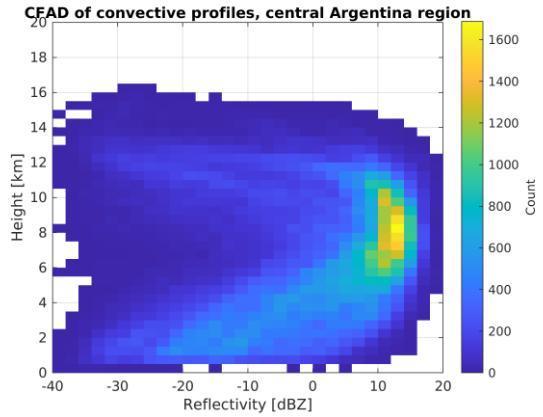


2701 profiles

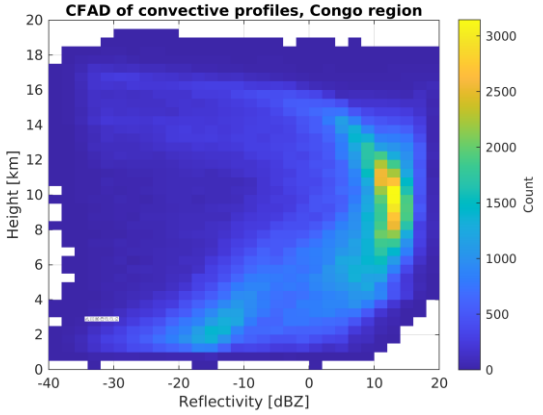




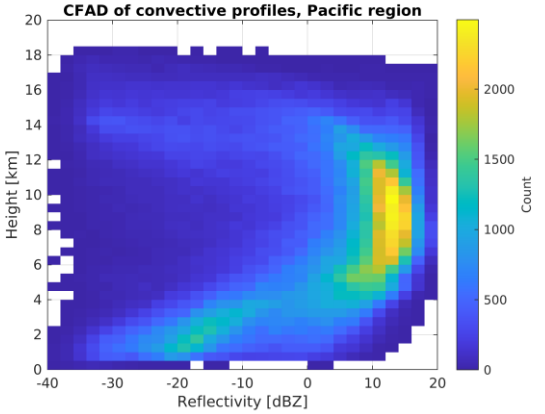
Liu, C., E. J. Zipser, and S. W. Nesbitt, 2007: Global Distribution of Tropical Deep Convection: Different Perspectives from TRMM Infrared and Radar Data. *J. Climate*, **20**, 489–503, https://doi.org/10.1175/JCLI4023.1.



1555 profiles



2956 profiles

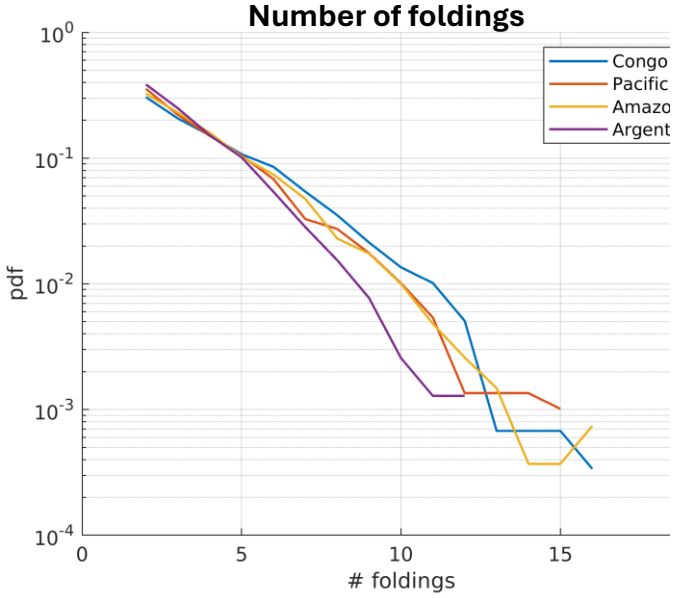


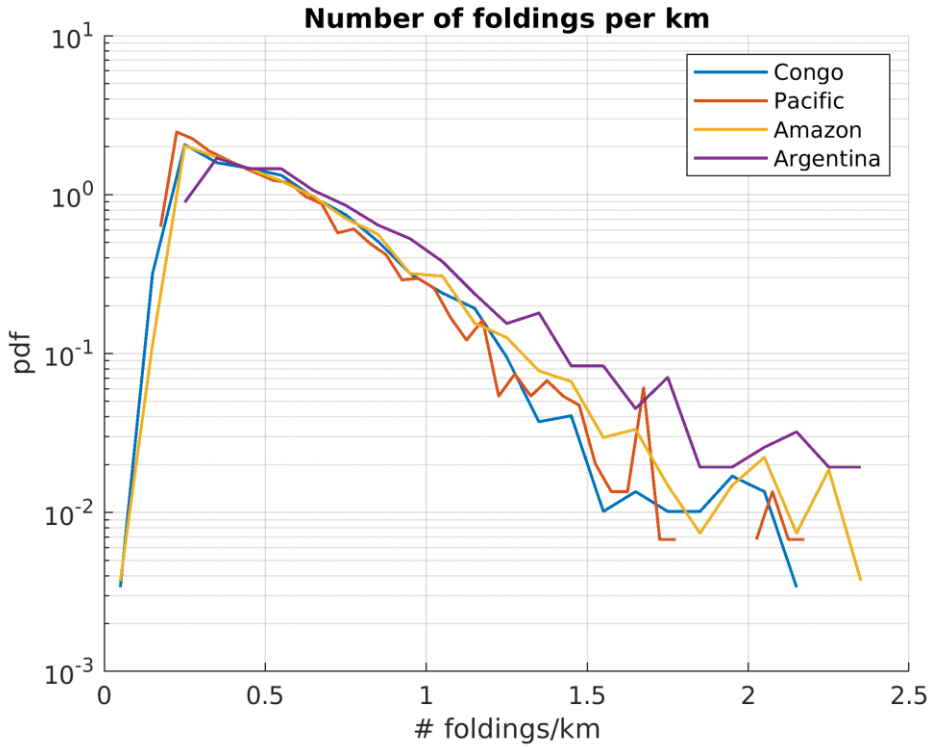
2962 profiles

Distribution of convective strength indicators

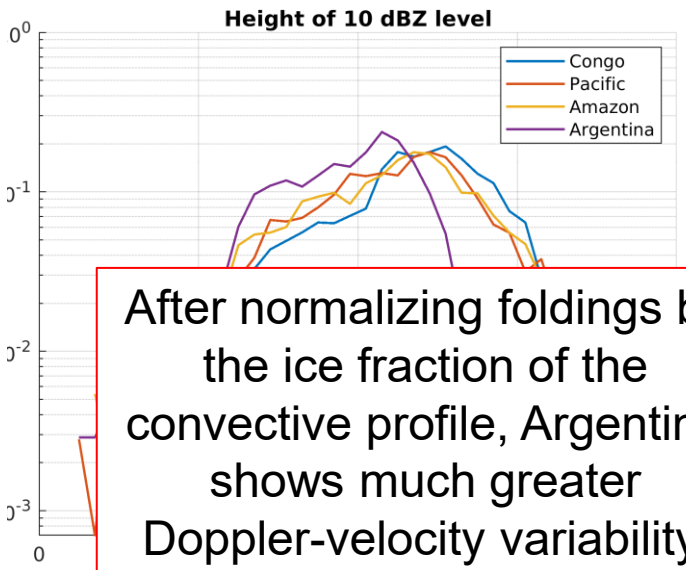
Due to sampling issues, the statistics for rare events may be too noisy to draw any conclusion.

Dynamic criteria





Morphological criteria



After normalizing foldings by the ice fraction of the convective profile, Argentina shows much greater Doppler-velocity variability, indicating stronger and more vigorous convection.

When looking at the tails, the Congo Basin exhibits deeper convective towers e.g. compared to central Argentina. The dynamic criteria seem to confirm that weaker convection is observed over Argentina.

Conclusions and future work

- EC-CPR Doppler velocities are **challenging to unfold** in convection, mainly because of the **low Nyquist velocity and high noisiness** of the velocities at km scale.

- Variability in Doppler velocity—quantified by **the number of foldings and the occurrence of high-velocity pixels**—is a useful *proxy for identifying convection and its strength*.

- The criteria are still under refinement; robust **validation/training dataset are needed.** These can be built by applying EC-CPR simulator to:

  - ❑ Airborne multi-frequency Doppler radar observations;

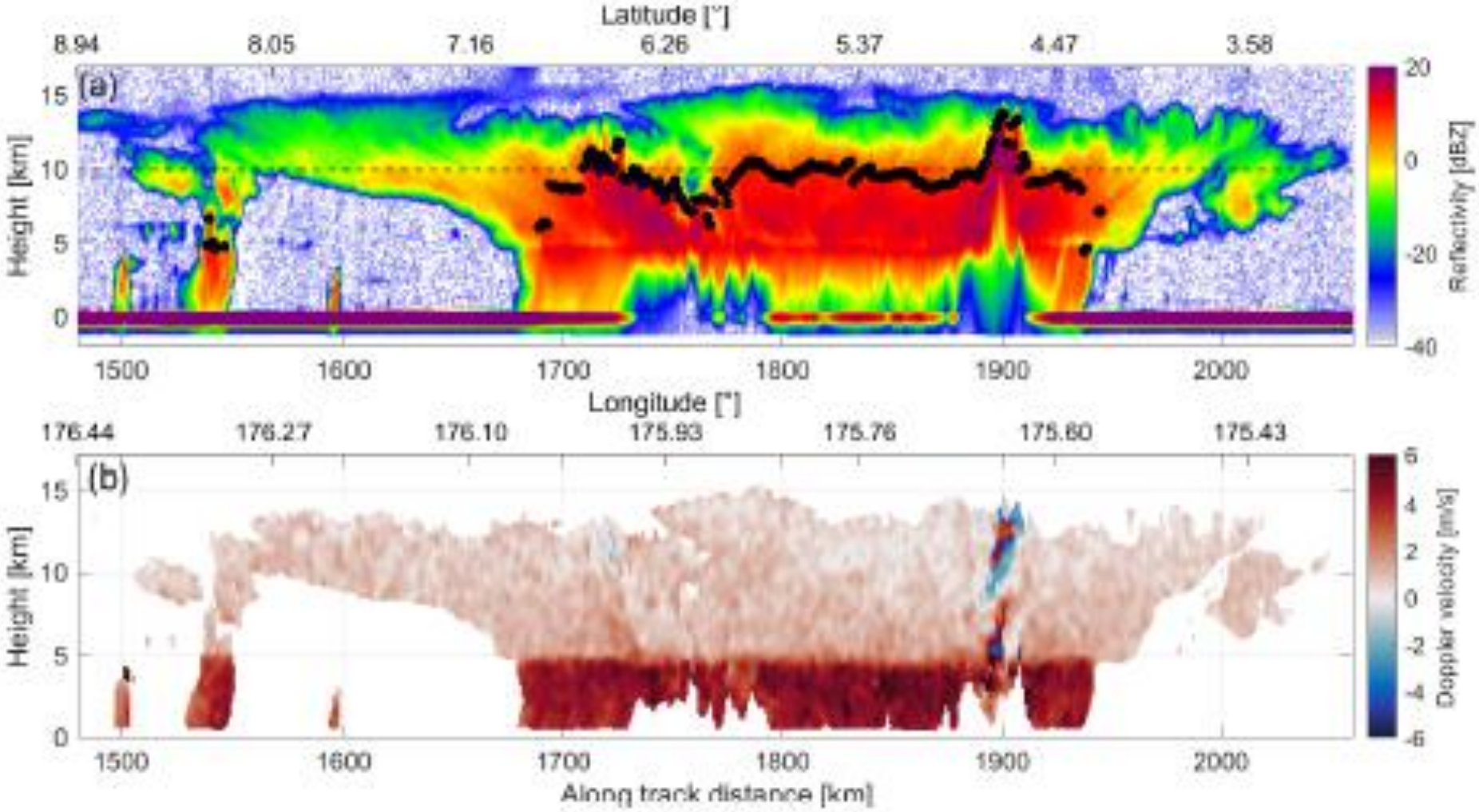
  - ❑ km-scale models of convective cores (synergy with INCUS mission).

- Once established, these criteria can be applied to assess **regional climatologies of convection**

Future work

- ➢ Keep expanding the dataset (improve stats of extremes);
- ➢ Instead of identifying convective profiles, characterize the convective cores in terms of horizontal & vertical extent and strength of the core mass flux.

Thank you for your attention!



Galfione et al., 2025
Atmos. Meas. Tech., 18, 6747–6763, 2025, https://doi.org/10.5194/amt-18-6747-2025

FUNDING

1) ESA VAMOS project

2) PRIN-2022 JHEM2M - CUP B53D23007140006 Convection characterization via synergistic GEO and LEO satellite observations.