Synergistic Observations of Tropical Cyclones from EarthCARE and Geostationary Satellites

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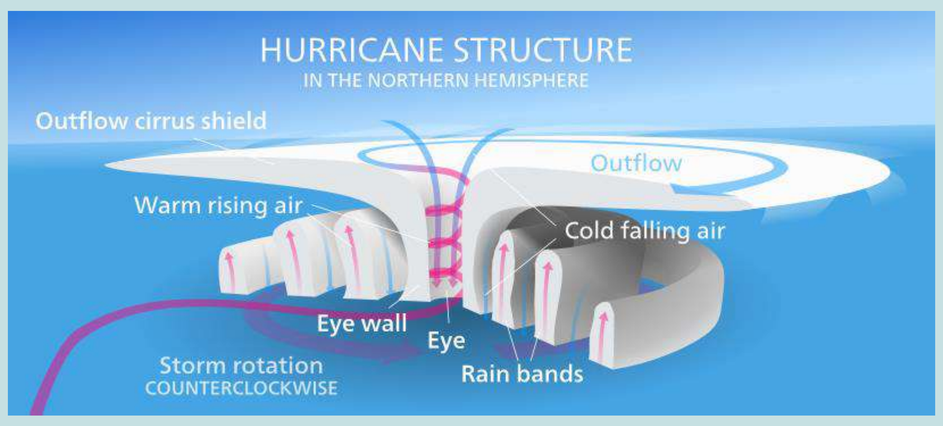
Introduction

Tropical Cyclones

- Tropical Cyclones (TCs) are large rotating cloud systems with lifetimes of several days.
- Geostationary satellite imagers such as MTG-FCI, Himawari-AHI or GOES-R ABI are essential for life cycle monitoring.
- However, geostationary observations mainly provide cloud-top information from the ice shield with very limited information on internal cloud processes.



Source: https://courses.ems.psu.edu/earth107/node/1045

- EarthCARE offers unique synergistic and vertically resolved observations to study TCs.
- EarthCARE observations already demonstrated strong coupling between cloud dynamics and microphysics inside tropical cyclones (Huang et al., 2026, ACP).

Key objectives

- Can EarthCARE contribute to answer key questions?
  - How is convection organized in the eye-wall and rain bands?
  - What is the link between updraft speed and storm intensity?
  - How do dynamics influence cloud microphysics?
- Connection of cloud top radiation with in-cloud microphysics and dynamics.
- Support life cycle studies (combination with geostationary satellites).
- Global TC statistics.

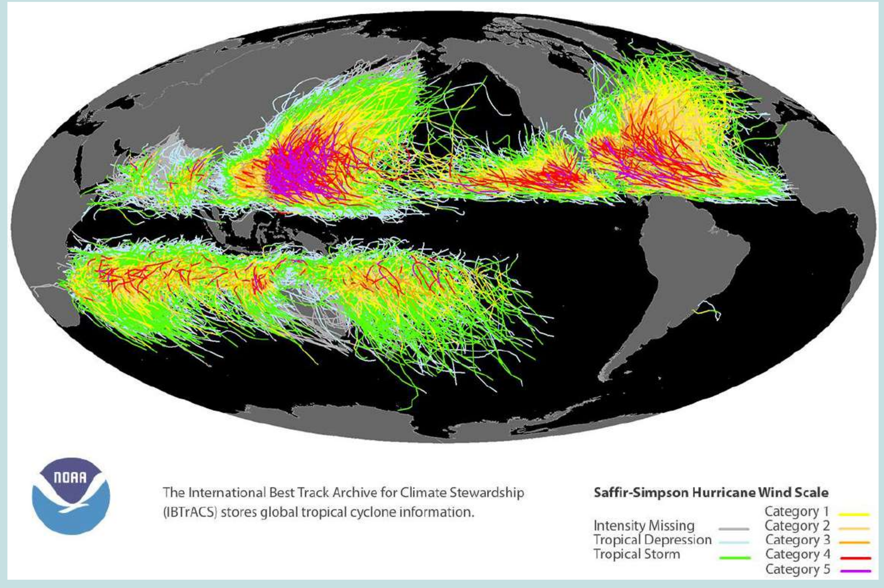
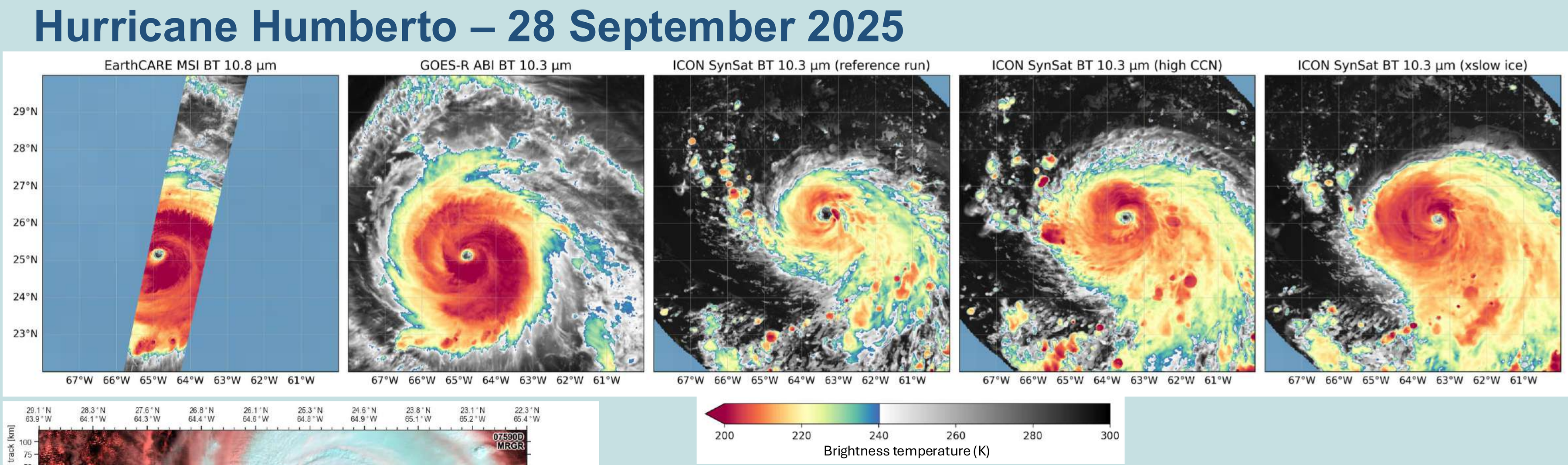


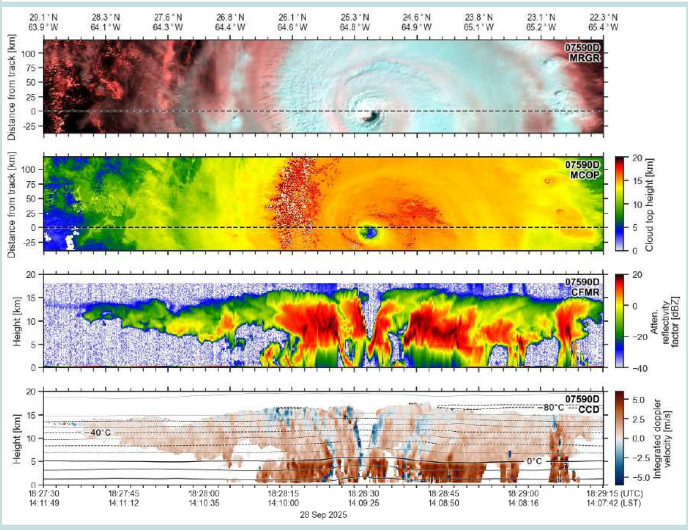
Fig.: Tropical cyclones recorded since 1850s until present. Source: https://www.ncei.noaa.gov/news/inventory-tropical-cyclone-tracks

- Highest TC activity in the western North Pacific (Typhoons), followed by North Atlantic and eastern Pacific (Hurricanes).
- TC activity strongly seasonal.

Life cycle analysis using GOES-R and ICON

Hurricane Humberto – 28 September 2025

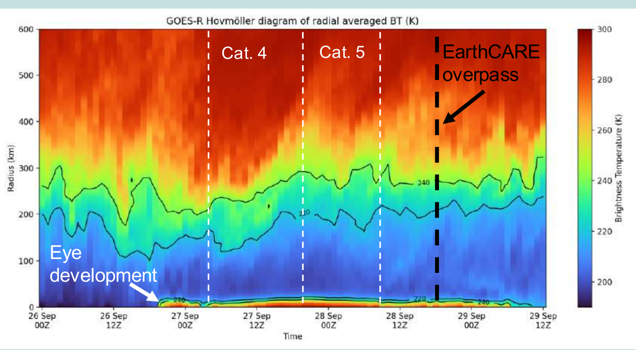


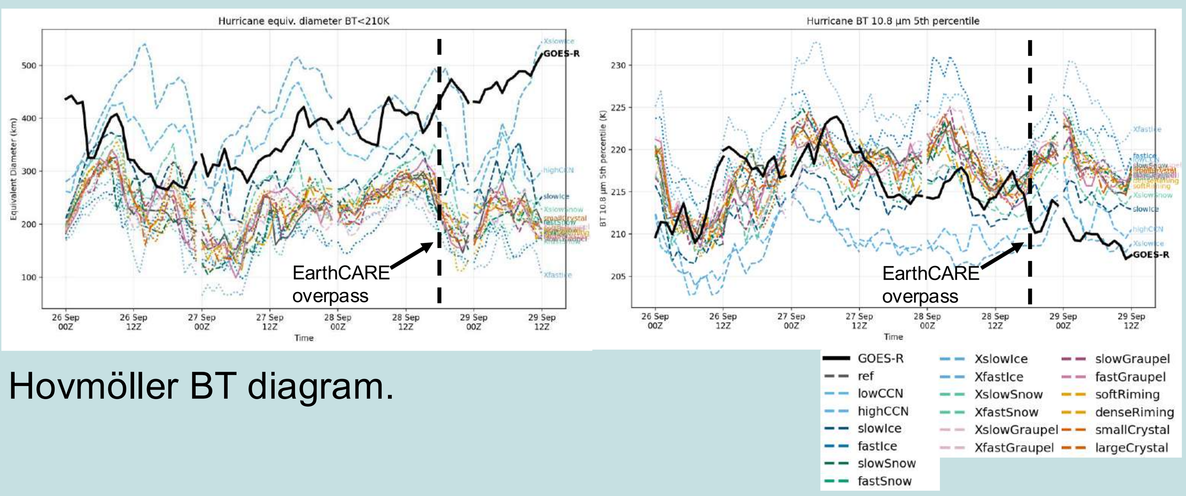


→ Figure created with earthcarekit (König et al., 2026)

- 1.2 km hurricane centric simulations (Senf et al., 2026, AMT) with 18 perturbations (each 30%) in fall velocities (ice, snow, graupel) and CCN concentration and freezing processes (following Naumann et al., 2025, ACP).
- Evaluation against GOES-R and EarthCARE using SynSat (for BT metrics) and PAMTRA (for CPR metrics).
- High CCN and double slow ice fall velocity agree best with observation.

→ Talk by Roxana Cremer on Thursday 15:18 BST

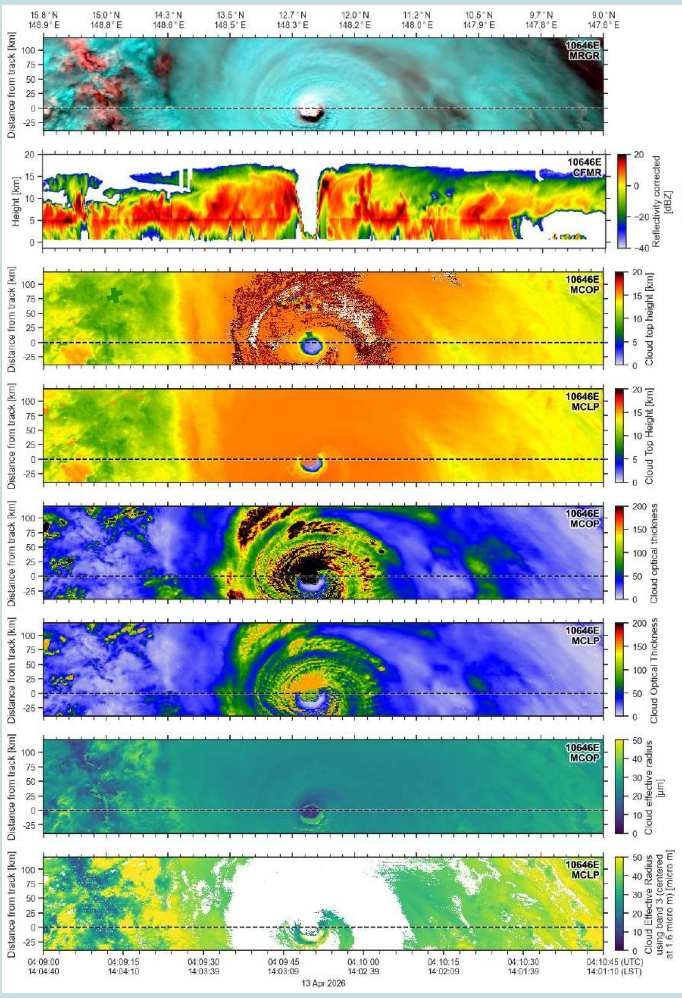


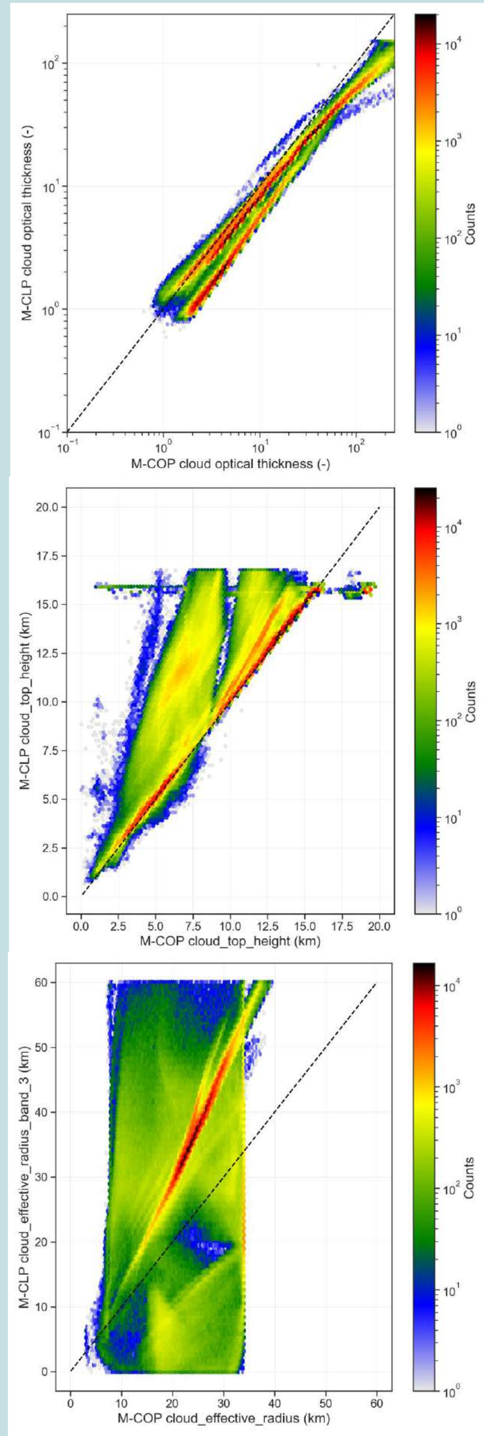


- Spiral bands become visible in the Hovmöller BT diagram.
- Cloud top BT colder during night

MSI L2a cloud product comparison M-COP vs. M-CLP

Typhoon Sinlaku – 13 April 2026





- M-COP and M-CLP (BC) both show issues for deep convective clouds.
- Cloud droplet effective radius not retrieved by the optimal estimation for the core of the typhoon, only the M-COP iterative retrieval.
- → Algorithm tuning ongoing.

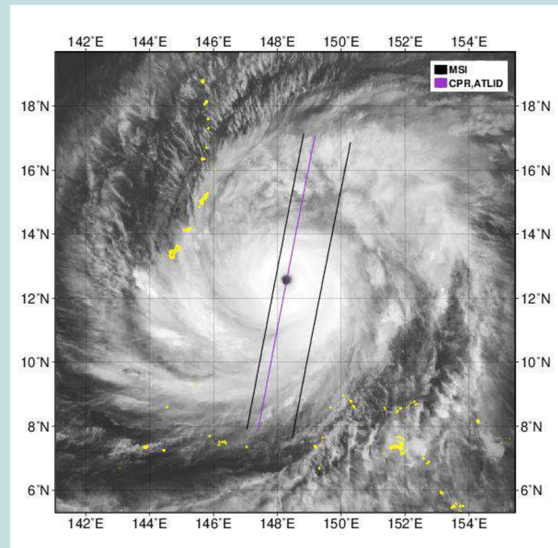


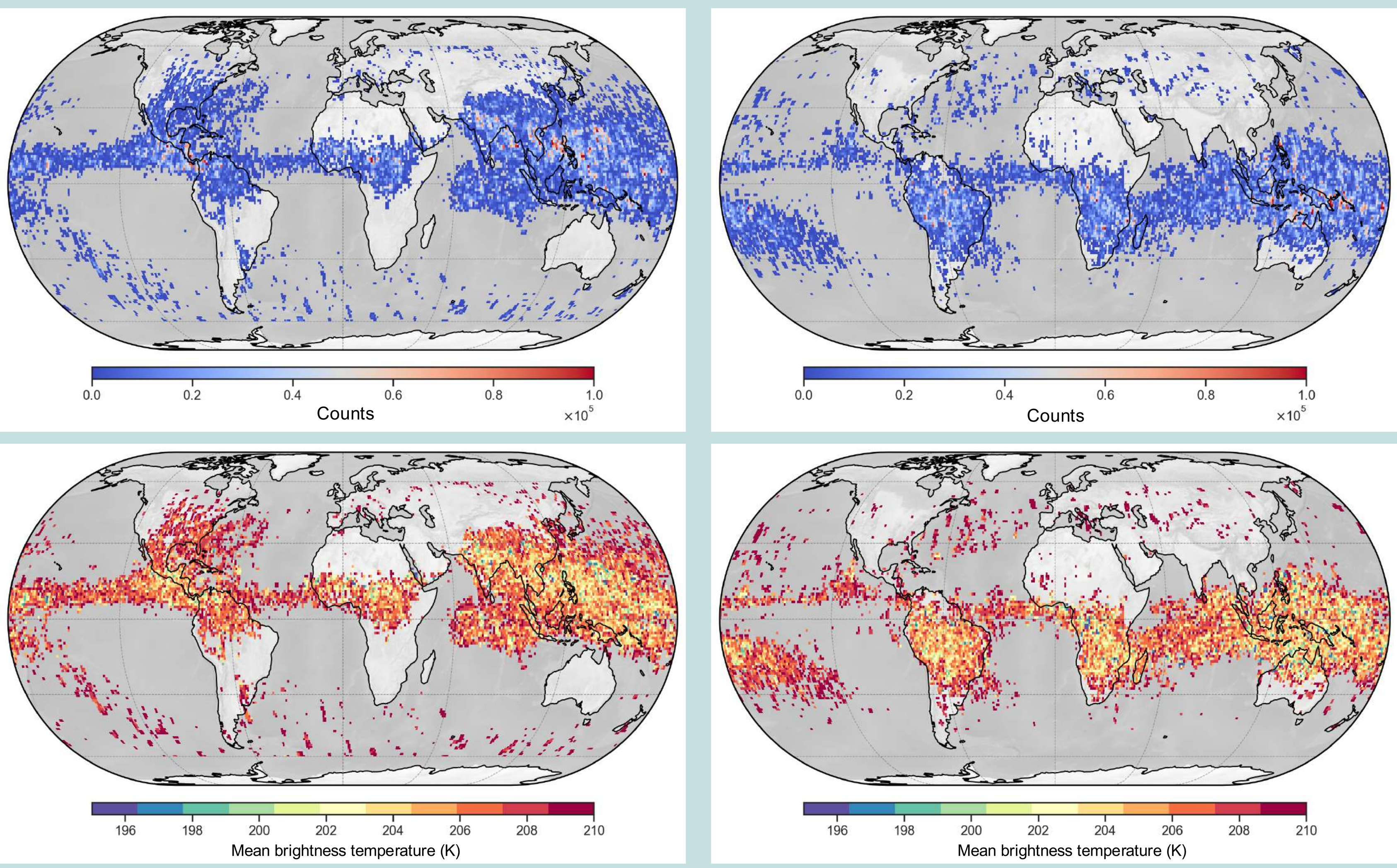
Fig. Himawari-9 ABI TIR brightness temperature with EarthCARE track.

→ Good agreement between M-COP and M-CLP for cloud top height and cloud optical thickness, but M-COP underestimation of effective radius.

→ Strong dependency on ice cloud microphysical model.

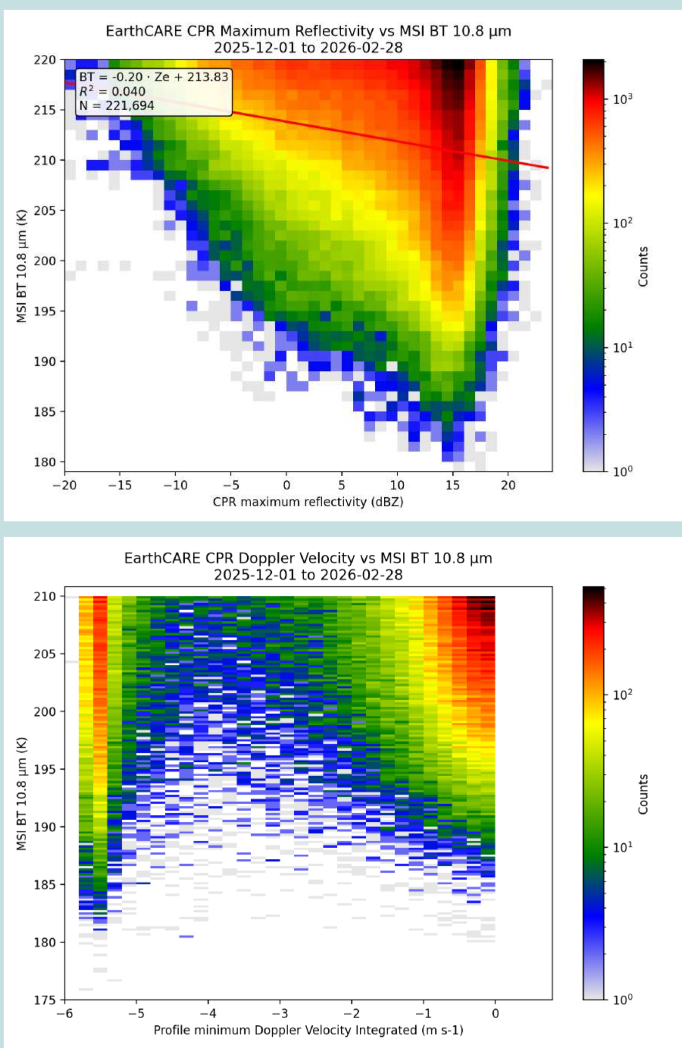
Global statistics from EarthCARE

Jun – Aug 2025 (MSI_RGR BA) / Dec 2025 – Feb 2026 (MSI_RGR BC)



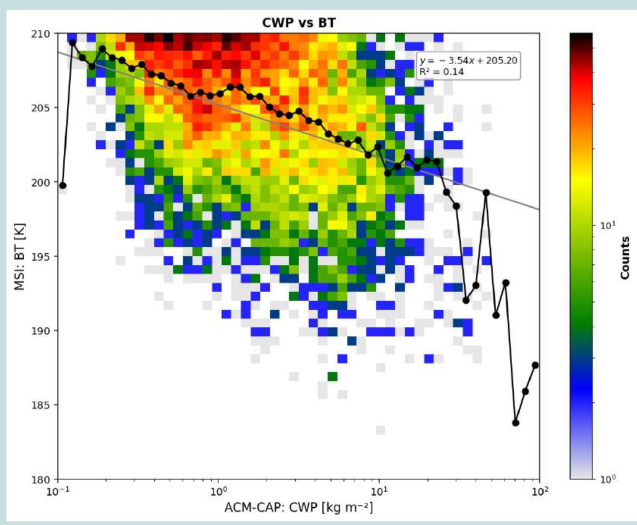
- MSI Level-1c TIR-2 (10.8 µm) brightness temperature at 1 degree global grid.
  - Top: Counts for BT<210K
  - Bottom: Mean BT (<210 K)
  - Single MSI threshold test alone as first proxy: Using active instrument synergy (limited to nadir track) or meteorological data (difference of cloud top BT and tropopause temperature) provide valuable additional information.

MSI vs. CPR



- Connection between very cold cloud tops and high CPR reflectivity.
- Minimum Doppler Velocity as proxy to identify updrafts.

MSI vs. ACM_CAP



- Higher ACM_CAP cloud water path for very cold MSI cloud top temperatures.

References

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EarthCARE 2026 Science and Validation workshop

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