Exploiting synergies between EarthCARE and ground-based supersites

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BACKGROUND

EarthCARE

- Global high-resolution vertical profiles of clouds and precipitation
- Four instruments providing synergistic observations of clouds, aerosols and radiation
- Satellite-perspective -> High sensitivity at high altitudes
  -> Limited sensitivity at low levels

ACTRIS/Cloudnet network

- 28 ground-based supersites across Europe *(incl. Arctic, Antarctic, Canary Island)*
- Combined measurements of clouds, aerosols, radiation
- Ground-based -> Reliable for low-level clouds
  -> Limited sensitivity at high altitudes

Objectives

- ➢ Evaluating EarthCARE and ground-based radar observations
- ➢ Identifying systematic differences between both observation datasets

DATA

- EarthCARE: CPR_FMR_2A product [baseline BA] *(ESA, 2025)*
- Cloudnet: Radar reflectivities (gas- & liquid-attenuation corrected) at 94 GHZ sites (15 across Europe) *(Hogan & O'Connor, 2004)*
- For all data: data available within 2024-07 – 2025-10
  vertical interpolation (between 500m to 20km, 100m steps)
- Phase separation:
  - EarthCARE: AC__TC__2B product [baseline BA] *(ESA, 2025)*
  - Cloudnet: Classification product *(Hogan & O'Connor, 2004)*
  - Merged Target-Classification

See poster by Ioanna Tsikoudi ***(Annex58)***

	Merged	Cloudnet	EarthCARE
Liquid	Droplets T>0°C [1] Droplets T<0°C [2]	Cloud liq. Droplets [1] & T>0°C Cloud liq. Droplets [1] & T<0°C	Liquid cloud (8) Supercooled liquid (18)
Rain	Drizzle or rain [3] Drizzle & droplets [4]	Drizzle or rain [2] Drizzle/rain & cloud liq. droplets [3]	Rain [5, 10, 11] Drizzling liquid cloud [9]
Ice	Ice [5]	Ice [4]	Snow classes [13, 14, 15, 16] Ice classes [19, 21]
Mixed-phase	Ice & droplets [6] Melting & ice possibly droplets [7]	Ice & supercooled droplets [5] Melting ice [6] Melting ice & cloud liq. droplets [7]	Heavy mixed phase precip. [6]; Snow & supercooled liquid [17]; Ice & supercooled liquid [20] Melting snow [12]

RESULTS

EarthCARE CPR vs. Ground-radar observations

- Ground-based: low-level clouds ⬆
- EarthCARE: high-level clouds ⬆
- Most sites: EC observed high-level clouds at higher altitudes

Caveats

- Different attenuation-correction:
  - EarthCARE: gas-correction
  - Ground: gas- & liquid-correction
- EarthCARE: Station CFADs very similar
  => 5° and 1° have similar results

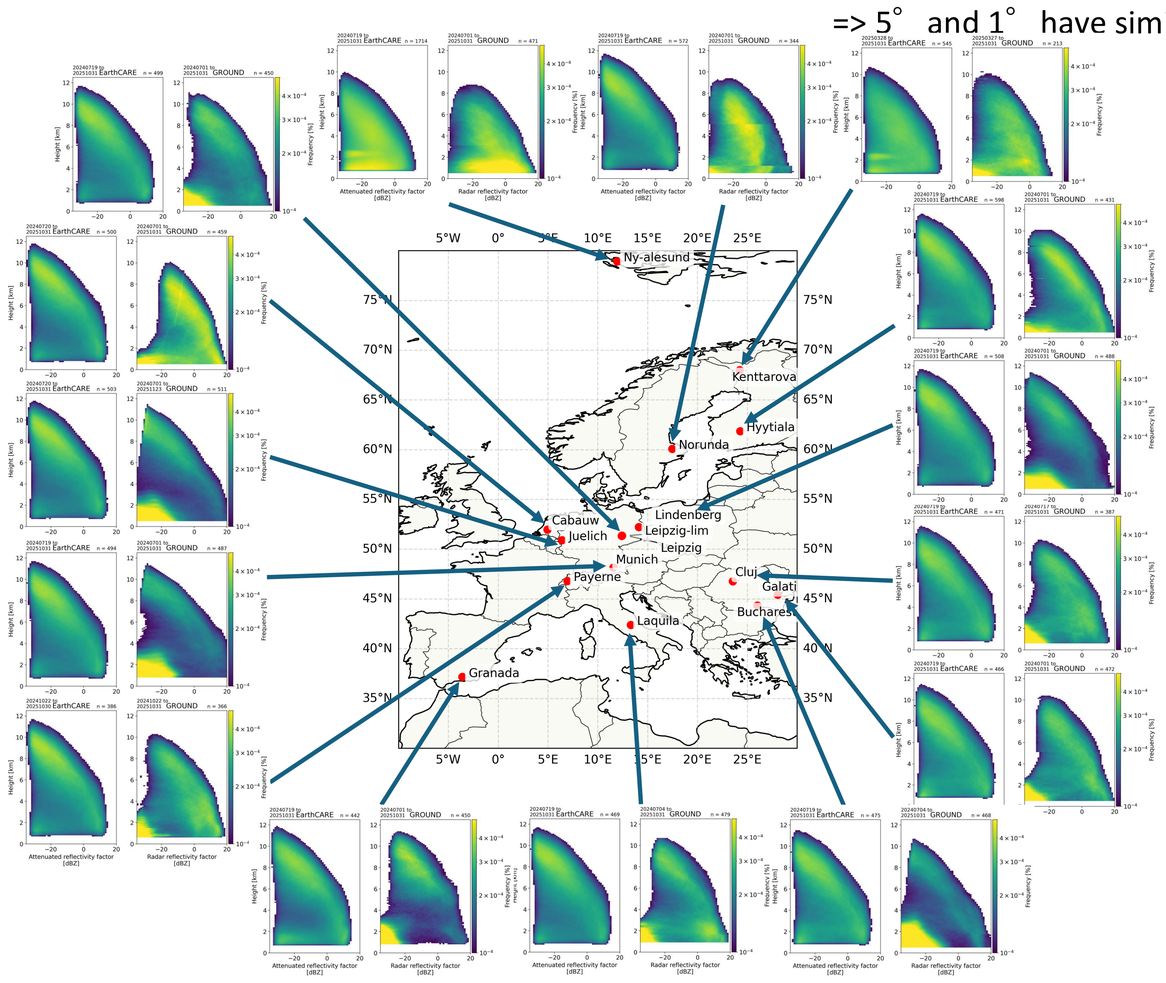

Fig. 1: Contoured Frequency by Altitude Diagrams (CFADs) for EarthCARE and ground-based radar observations at Cloudnet sites with a 94 GHz radar. Frequencies of occurrence are normalized by the total number of occurrences. EarthCARE observations are considered within a 5° circle around each site, and are corrected for gas-attenuation *(left)*. Ground-based observations are in-situ measurements and corrected for gas- and liquid-water-attenuation *(right)*.

Phase separation *(preliminary)*

- Differences mostly in liquid & mixed-phase (Z > 0dBZ)
- Liquid phase: EarthCARE over entire dBZ-range
- GROUND-rain: Very homogeneous

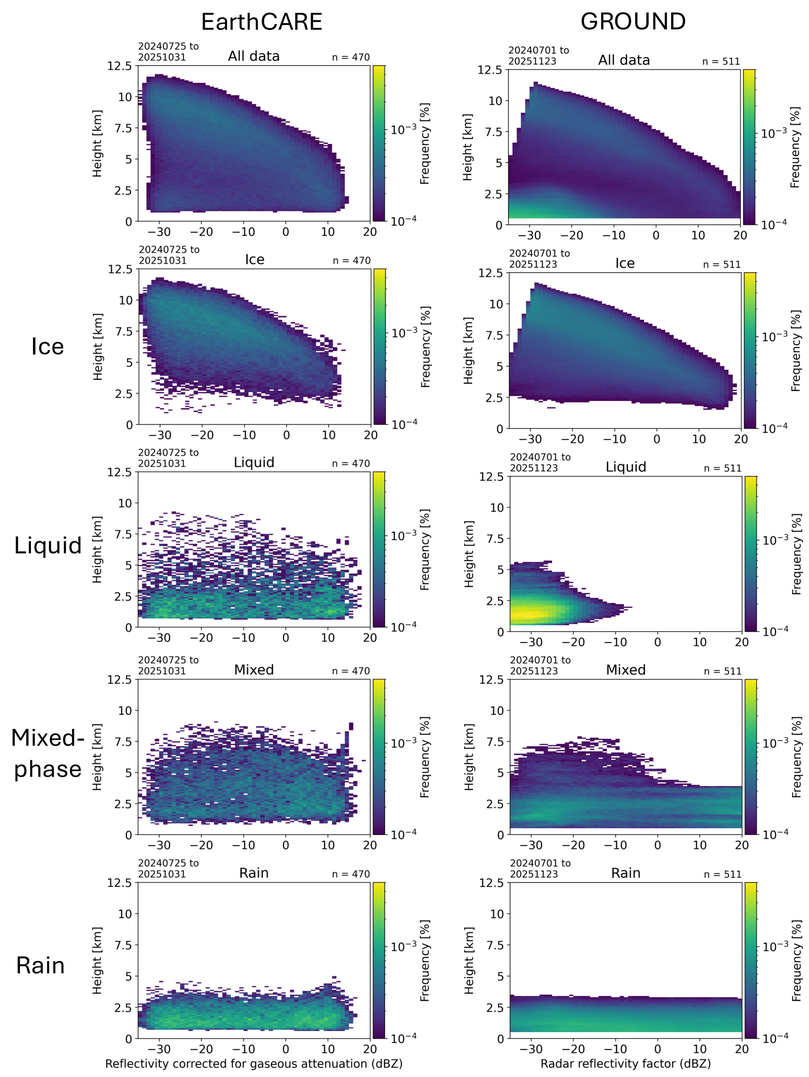

Fig. 2: Separation of Radar reflectivity measurements into different cloud phases for the Cloudnet station at Juelich, Germany. The EarthCARE data *(left)* represents the radar observations within a 5° circle around the site. The ground-based observations *(right)* are in-situ.

OUTLOOK

- ➢ Continued evaluation of ground-based measurements
- ➢ Target-Classifications to identify differences of different cloud phases between EarthCARE & ground-based measurements
- ➢ Further analysis: Impact of seasonal and diurnal cycle

Quantitative assessment:

- What proportion of low-level (high-level) clouds does EarthCARE (ground-based) miss?
- How does IFS model data compare to these observations?

Regime-Clustering:

- Identify different cloud types/ regimes
  (also w.r.t. different cloud phases, seasons, etc.)
- Compare cloud clusters between the different datasets

Comparison with the IFS:

- Use of Forward-Model at Cloudnet-sites & along EarthCARE tracks
- Evaluate "model performance" in respect to low-level clouds
- Focus on the representation of cloud processes within the IFS

References

European Space Agency, et al,2025,"EarthCARE CPR FMR Level 2A",(version BA), https://doi.org/10.57780/eca-c094213

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Hogan & O'Connor (2004): Facilitating cloud radar and lidar algorithms: the Cloudnet Instrument Synergy/Target Categorization product. https://www.met.reading.ac.uk/~swrhgnrj/publications/categorization.pdf