Evaluation of EarthCARE synergistic cloud retrievals using ground-based observations at the Lampedusa Station

EUROPEAN SPACE AGENCY

Poster P057

G. Pace[1,*], D. Meloni[1], V. Ciardini[1], L. De Silvestri[1], T. Di Iorio[1], A. di Sarra[1], F. Monteleone[1], M. Picchiani[2], D. Sferlazzo[1]

[1]ENEA, Department of Sustainability Italy; [2]ASI, Italy * giandomenico.pace@enea.it

INTRODUCTION

Within the framework of the EC-ValMed.it project, ENEA and CNR are actively involved in the validation of EarthCARE (EC) Level-2 products. Ground-based observations acquired at the ENEA Station for Climate Observations on Lampedusa Island (35.52° N, 12.60° E) are used for this purpose. The geographical characteristics of Lampedusa—flat terrain (maximum elevation ~130 m), small surface area (~20 km^2), and its location approximately 130 km from the nearest coastline—make it an ideal site for monitoring clouds and precipitation over open sea conditions. Due to the EC orbit, overpasses occur approximately twice per month within a distance of 5–15 km from the station. Considering also the higher spatial homogeneity of atmospheric processes over the open ocean compared to regions with complex orography, these conditions provide an excellent opportunity to observe and analyse nearly the same air mass from both satellite and ground-based perspectives.

This work presents a comparison of EC Level-2 products derived from the overpasses on 7 January and 3 November 2025, including the synergistic retrieval **ACM-CAP** (hereafter CAP; Mason et al., 2023), and the microphysical retrieval **AC_CLP** (hereafter CLP; Sato et al., 2025), commissioned respectively by ESA and JAXA, with retrievals obtained from ground-based observations at the ENEA Lampedusa station. The station is part of the ACTRIS National Facility, and its data are processed using the **Cloudnet** processing chain (hereafter LMP; Illingworth et al., 2007). *For additional results of the EC-Valmed.it project see posters: P010 by E. Adirosi, P026 by D. Meloni, P028 by D. Meloni and P035 by S. Sensi.*

Overpass date and time	EarthCARE products and version	Minimum distance from Lampedusa, km
07/01/2025 00:47:50.29	ACM_CAP_2B, BA	15.6
	CPR_CLP_2AS, Bb	
03/11/2025 00:45:17.72	ACM_CAP_2B, BA	5.9
	AC_CLP_2BS, Bb	

***Table 1** summarizes the main information regarding the selected overpasses, as well as the corresponding products and product versions used in this study.*

7 January 2025

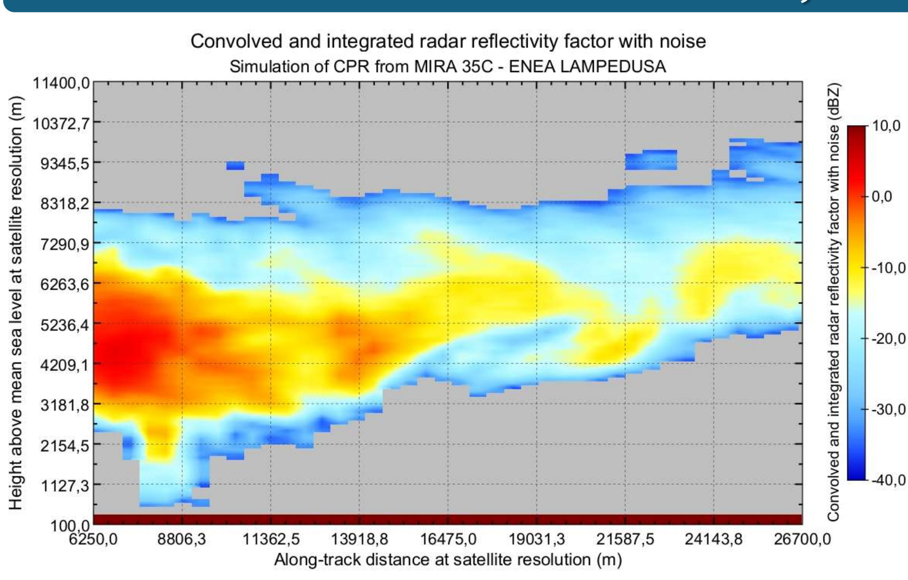


***Figure 1a.** Behaviour of the simulated CPR reflectivity profiles as a function of the along-track distance, obtained by applying the Cloudnet retrieval algorithm (Pfitzenmaier et al. 2025) to the DCR data and accounting for radar-frequency differences, vertical resolution, and CPR noise signal.*

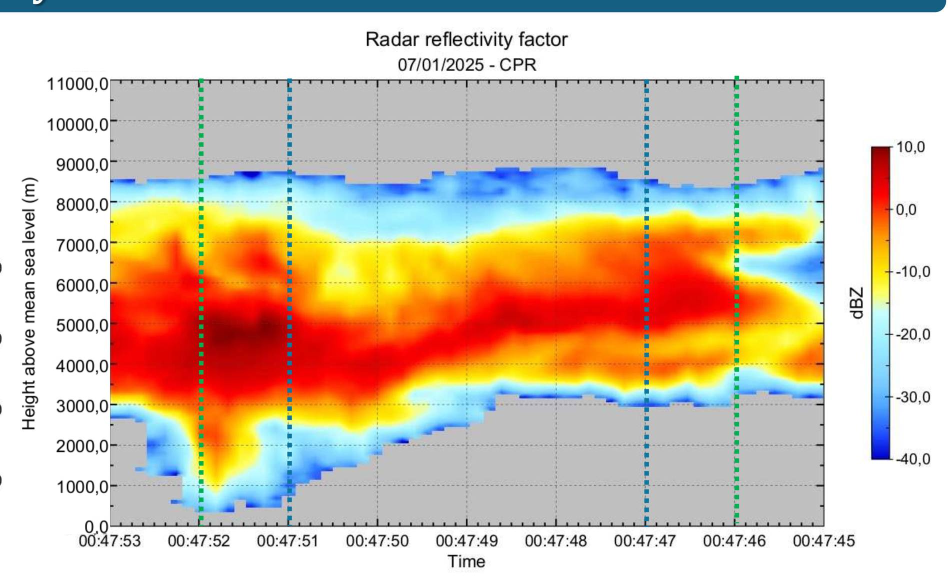
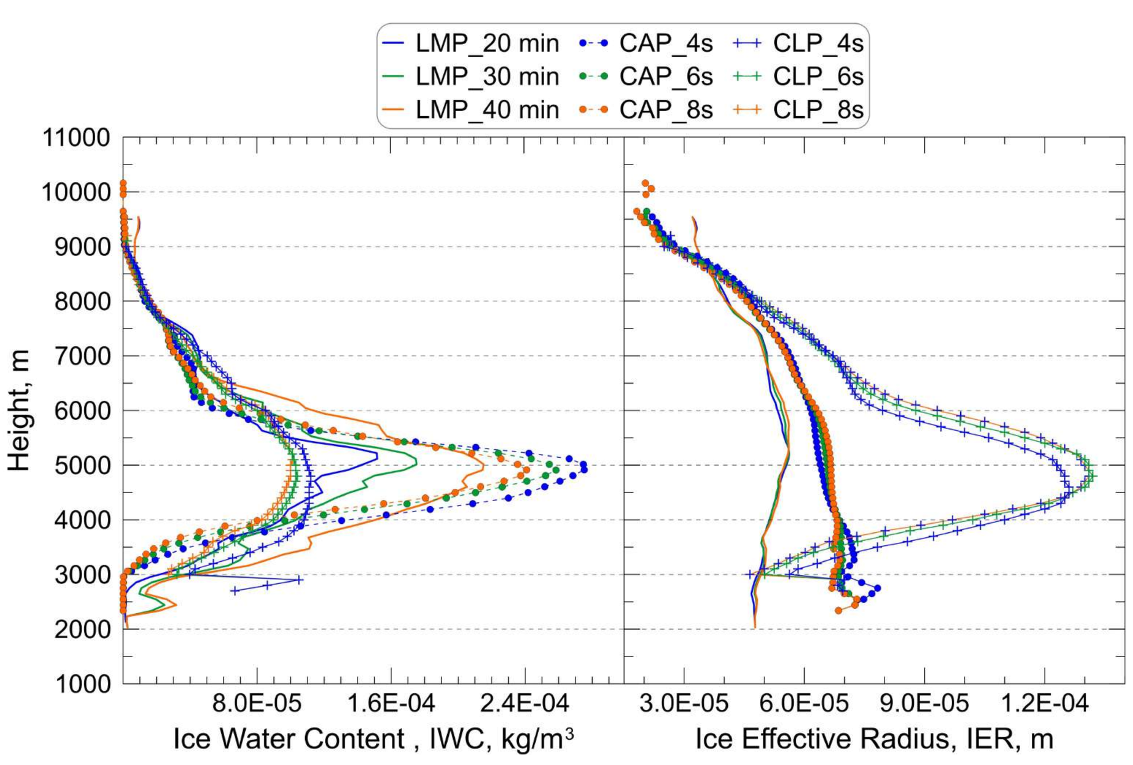


***Figure 1b.** CPR reflectivity over an 8 s interval centered at 00:47:49; blue and green dotted lines mark the 4 and 6 s averaging windows used to derive mean satellite profiles.*

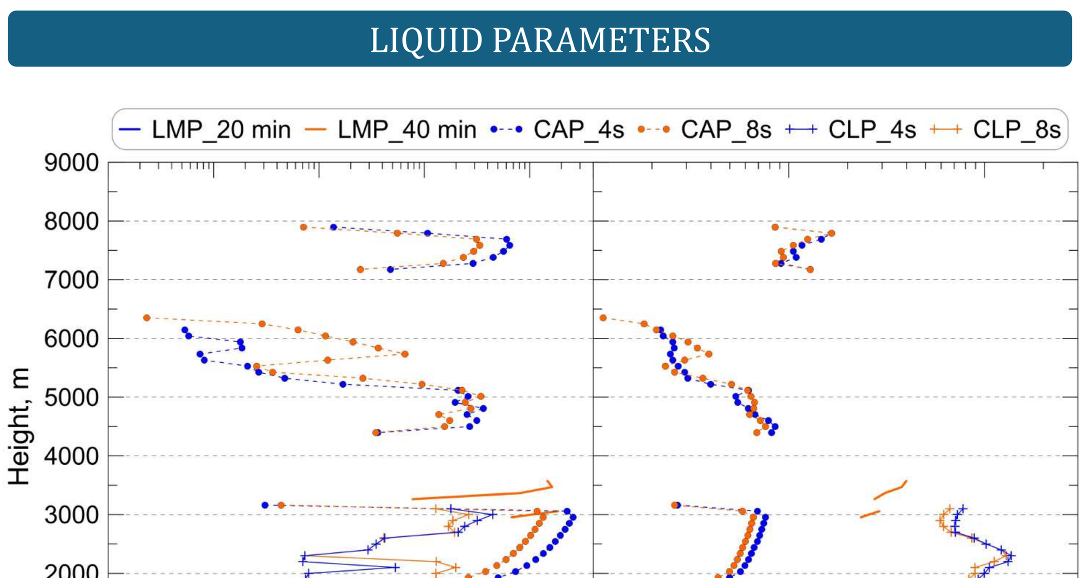


ICE PARAMETERS

A comparison of ice water content (IWC) and ice effective radius (IER) from the three retrievals is shown in **Fig. 2**. Although all retrievals exhibit close agreement in the vertical distribution of IWC and consistently identify a relative maximum between 4500 and 5000 m, substantial differences between CAP and CLP are also presented. CAP shows a pronounced IWC peak, which in both the 40-min and 8-s average well agrees with the Cloudnet retrieval. In contrast, at this altitude CLP displays a marked peak in IER, reaching values of about 100 µm, significantly larger than the corresponding values of 70 µm (CAP) and 55 µm (LMP).

***Figure 2.** Left and right panels show ground-based and satellite-derived mean IWC and IER profiles, respectively. Ground-based and satellite averages over 20, 30 and 40 minute intervals (blue, green and orange lines), and over 4-6 and 8-second intervals (blue, green and orange with symbols), are displayed. LMP, CAP, and CLP profiles appear as lines, lines with circles, and lines with crosses, respectively.*

LIQUID PARAMETERS



Compared to Cloudnet, both CAP and CLP products detect liquid water not only near the cloud base (3000–3500 m) but also below, down to ~500 m. CAP additionally identifies liquid water at higher altitudes, up to ~8000 m. These differences in liquid water detection represent the main qualitative distinction among the three products. In the layer where all retrievals consistently detect liquid water (2950–3050 m), LWC values are comparable (4–10 × 10^{-5} kg m^{-3}). Cloudnet retrieves droplet effective radii of ~25 µm, whereas CAP and CLP show smaller (6–7 µm) and larger (~65 µm) values, respectively. Below 3000 m, CAP exhibits higher LWC and smaller droplet sizes than CLP.

***Figure 3.** Left and right panels show ground-based and satellite-derived mean IWC and IER profiles, respectively. Ground-based and satellite averages over 20 and 40 minute intervals (blue and orange lines), and over 4 and 8-second intervals (blue, and orange with symbols), are displayed. LMP, CAP, and CLP profiles appear as lines, lines with circles, and lines with crosses, respectively.*

DOPPLER VELOCITY

The vertically averaged doppler velocity profiles are relatively consistent between 3000 and 9000 m. Between 2500 and 7500 m the agreement is particularly good, with differences below 0.2–0.3 m s^{-1}. Larger discrepancies occur near cloud base and between 2000 m and the surface, where EC measurements show increasing fall speeds up to 3.5 m s^{-1}, while ground-based observations decrease to ~2 m s^{-1}.

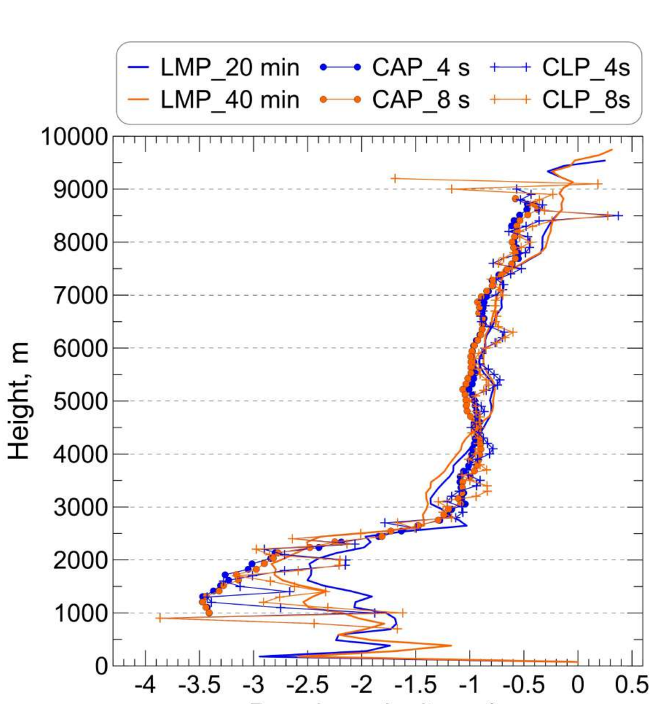


***Figure 4.** Temporal mean vertical doppler velocity profiles measured from the ground and from EarthCARE (ground, solid lines; satellite, solid lines with circles and crosses derived respectively from CAP e CLP products).*

3 November 2025

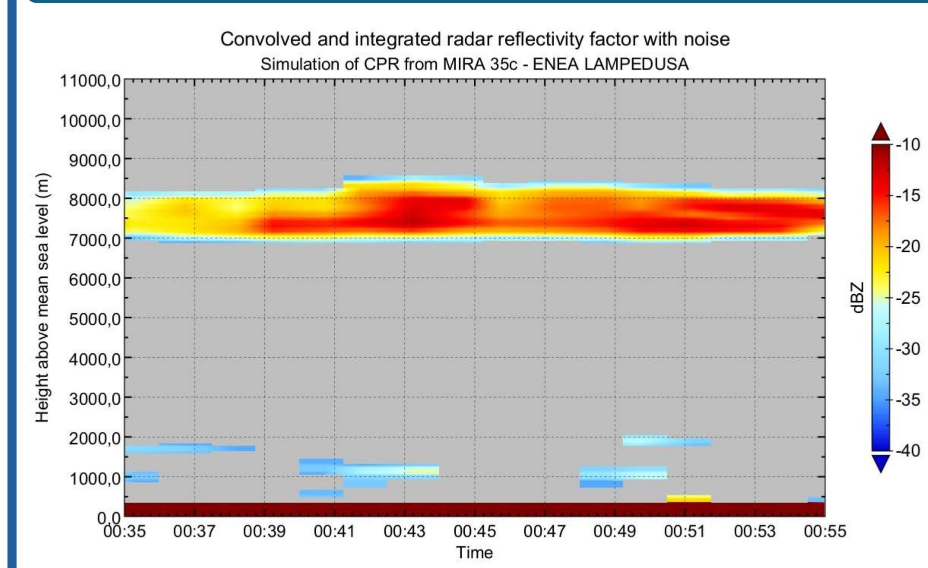


***Figure 5a.** Behaviour of the simulated CPR reflectivity profiles as a function of the along-track distance, obtained by applying the Cloudnet retrieval algorithm (Pfitzenmaier et al. 2025) to the DCR data and accounting for radar-frequency differences, vertical resolution, and CPR noise signal.*

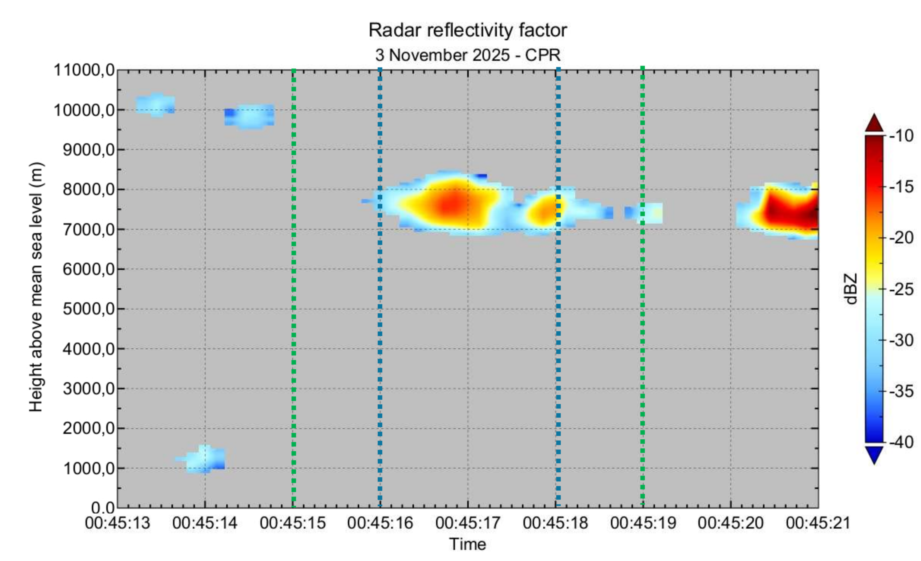
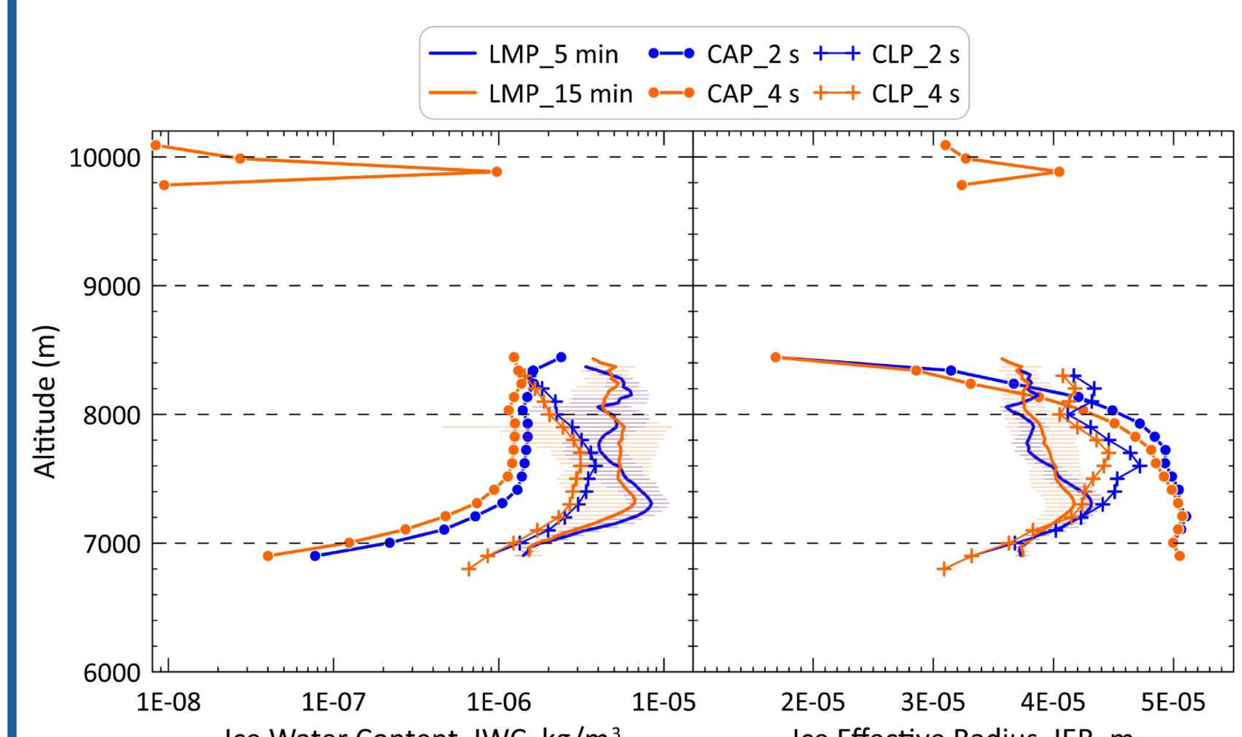


***Figure 5b.** CPR reflectivity over an 8 s interval centered at 00:45:17; blue and green dotted lines mark the 2 and 4 s averaging windows used to derive mean satellite profiles.*

ICE PARAMETERS



The comparison between IWC and IER profiles derived from EC and ground-based observations at Lampedusa is based on averages over 2–4 s for the satellite and 5–15 min for ground-based data (**Fig. 6**). Shorter averaging windows than in the January 2025 case were adopted due to the reduced satellite–ground separation and the higher scene homogeneity. The profiles show very good agreement in cloud base and top heights; however, the 15 min CAP average (orange solid line) reveals a thin layer around 10 km not detected by LMP, indicating that shorter averaging intervals better represent the true simultaneity of the observations.

***Figure 6.** Left and right panels show ground-based and satellite-derived mean IWC and IER profiles. Ground-based and satellite averages respectively over 5-15 minutes intervals (blue, and orange lines), and over 2-4 second intervals (blue, and orange with symbols), are displayed. LMP, CAP, and CLP profiles appear as lines, lines with circles, and lines with crosses, respectively. The IWC and IER standard deviation evaluated with Cloudnet retrieval are shown as horizontal error bars associated with the LMP profiles.*

The CAP retrieval shows nearly constant IWC (~1.5 × 10^{-6} kg m^{-3}) from cloud top to ~300 m above the base, followed by a sharp decrease below 10^{-7} kg m^{-3}. In contrast, the CLP profile increases from cloud top to a maximum of ~4 × 10^{-5} kg m^{-3} at 7.6 km, then decreases to ~6 × 10^{-7} kg m^{-3} at the base. Cloudnet IWC remains more uniform (~5 × 10^{-5} kg m^{-3}), with a decrease towards the base (~1.5 × 10^{-6} kg m^{-3}).

IER profiles are overall comparable: Cloudnet ranges between 37–41 µm; CAP increases from ~20 µm (top) to ~50 µm (base); CLP shows a weaker increase from ~42 µm to ~47 µm near 7.6 km, followed by a decrease to ~37 µm at the base. Overall, CAP exhibits a strong decrease (increase) in IWC (IER) from top (base) to base (top). CLP suggests a weaker relative maximum of both IWC and IER within the cloud interior, while Cloudnet shows a smaller maximum located ~400 m above the cloud base.

SUMMARY

Cloud systems observed during two EC overpasses in proximity to the ENEA Lampedusa station were compared with ground-based measurements. The analysis is based on three different synergistic retrievals, ACM-CAP and AC-CLP applied to EC data, and Cloudnet applied to Lampedusa observations. The overpass of 7 January 2025 sampled a complex cloud system at ~15.5 km from the ENEA Lampedusa station, including both ice and liquid clouds, whereas the overpass of 3 November 2025 sampled a relatively homogeneous thin cirrus at ~5.9 km from the station.

ICE PARAMETERS

7 January (thick cloud case) – CAP and Cloudnet show qualitative good agreement in the IWC vertical structure and peak values near 5000 m, with only minor differences in IER. CLP reproduces the overall IWC distribution, but shows significantly lower IWC and larger IER at the IWC peak compared to Cloudnet and CAP.

3 November (thin cloud case) – The three retrievals provide overall consistent results, although differences in the vertical profile behaviour most probably reflect the underlying assumptions of each retrieval. Increasing IWC values are observed for CAP, CLP, and Cloudnet, respectively, while decreasing IER values are found for CAP, CLP, and Cloudnet. Overall, the analysis suggests that CAP tends to retrieve higher IWC than CLP, while CLP tends to retrieve larger IER.

LIQUID PARAMETERS

• *7 January* – The largest differences among retrievals concern liquid water detection: CAP identifies multiple liquid layers, CLP only below 3000 m, while Cloudnet detects a thin liquid layer at the ice-cloud base.

DOPPLER VELOCITY

• *7 January* – Doppler-derived hydrometeor fall speeds are in good agreement between 3000 and 7500 m, with larger discrepancies near cloud top and below 2000 m.

References

Illingworth et al.,, *Bull. Amer. Meteor. Soc.*, 88, 883–898, 2207, https://doi.org/10.1175/BAMS-88-6-883.
Mason at al., *Atmos. Meas. Tech.*, 16, 3459–3486, 2023, https://doi.org/10.5194/amt-16-3459-2023.
Pfitzenmaier et al., *Geosci. Model Dev.*, *18*(1), 101-115, 2025, https://doi.org/10.5194/gmd-18-101-2025.
Sato et al. , Atmos. Meas. Tech., 18, 1325–1338, 2025, https://doi.org/10.5194/amt-18-1325-2025.

EarthCARE 2026 Science and Validation workshop

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

Acknowledgements

This work was supported by ASI by the EC-ValMed.it project (Agreement n. 2024-1-HB.0). It is part of the activity carried out in the frame of the ESA projects EVID05 and EVID11. We acknowledge ACTRIS and Finnish Meteorological Institute for providing the data set which is available for download from https://cloudnet.fmi.fi and ECMWF for providing IFS model data.