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cnes IPSL ACTRIS Centre for Cloud Remote Sensing

THE GROUND-BASED ACTRIS CLOUD REMOTE SENSING NETWORK AND ITS USE FOR THE VALIDATION OF EARTHCARE SATELLITE OBSERVATIONS

Bernhard Pospichal, Lukas Pfitzenmaier, Nathan Feuillard, Felipe Toledo-Bittner, Martial Haeffelin, Ewan O'Connor, Pavlos Kollias, Ulrich Löhnert

ACTRIS – Aerosol Cloud and Trace Gases Research Infrastructure

ACTRIS = fundamental **European research infrastructure for short-lived atmospheric constituents**

ACTRIS provides highly reliable information on

- the **four-dimensional distribution** of aerosol, clouds and reactive trace gases, including **long-term trends**
- the **processes** that control the life cycles of short-lived atmospheric constituents

ACTRIS

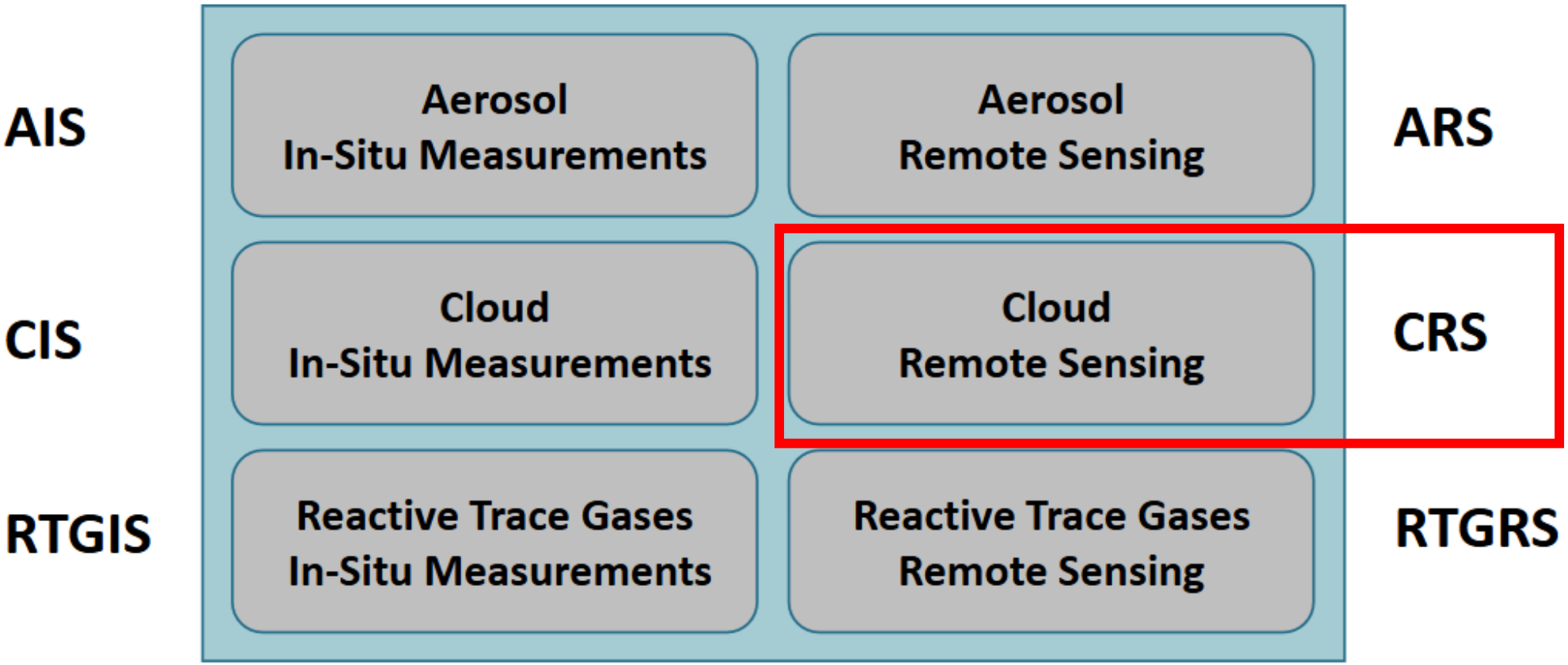
- is a **distributed pan-European research infrastructure**
- provides **effective access for a wide user community**
- is part of the **ESFRI Roadmap** since 2016 and **Landmark** since 2021
- was established as **ERIC on 25 April 2023**

https://www.actris.eu/

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Design					Preparation				Implementation				Operation		→	

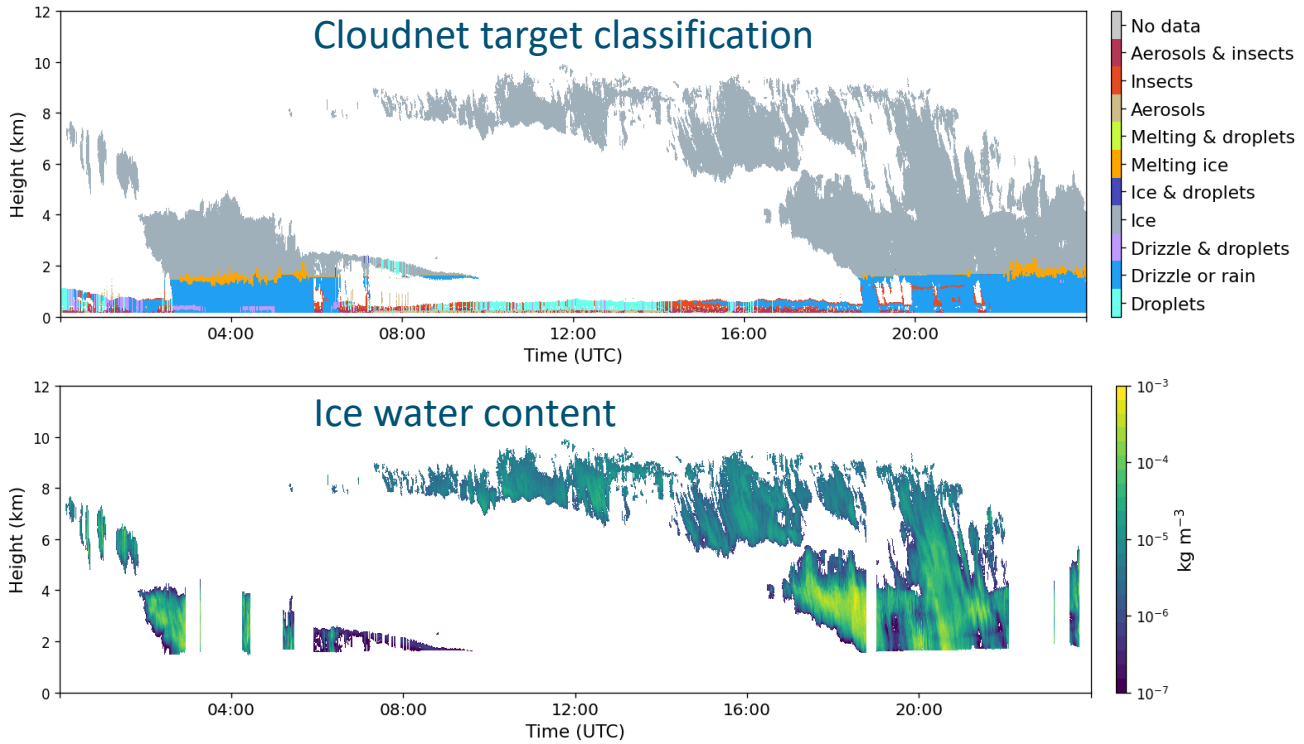
ACTRIS – Aerosol Cloud and Trace Gases Research Infrastructure

Six observational components



ACTRIS cloud remote sensing

- Cloudnet started about 20 years ago as a EU project, now Cloudnet is part of ACTRIS
- Products: **Cloudnet target classification** (cloud and precipitation types)
- Cloud liquid water and ice water content
- Further synergy products in development
  - Water vapor profiles
  - Profiles of the 3D wind vector
  - Precipitation type (polarimetric radar variables)
  - Boundary-layer height
  - Boundary-layer classification
  - Combined Aerosol/Cloud target classification



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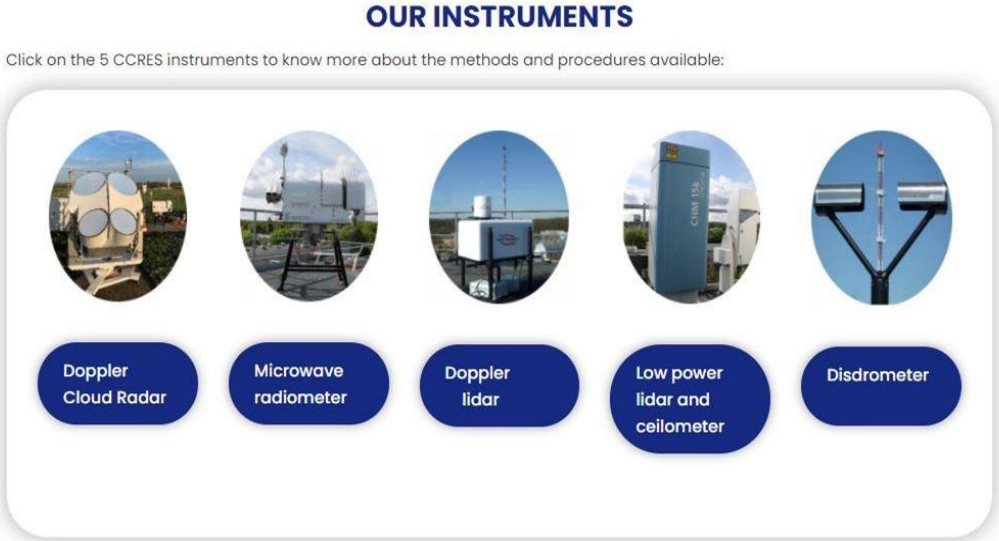
Introduction to CCRES and CLU

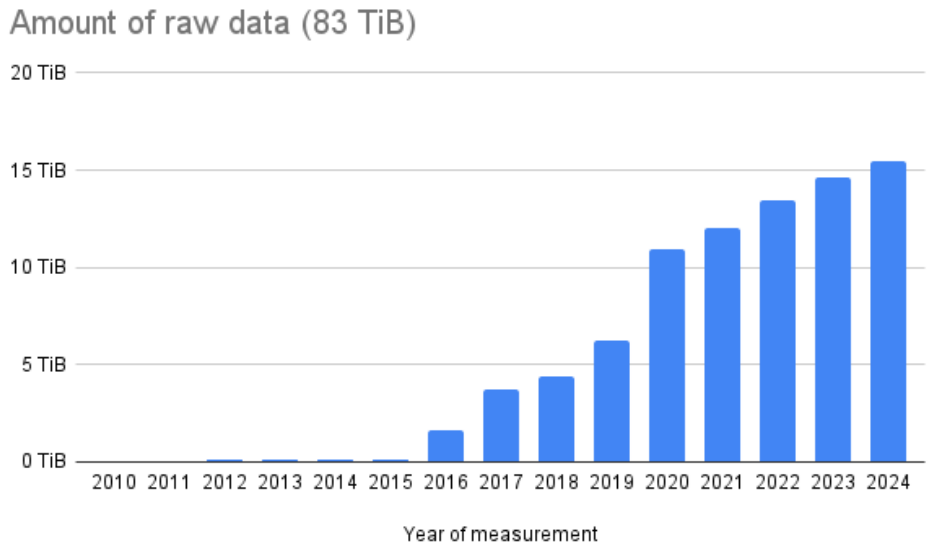
The **Centre for Cloud Remote Sensing (CCRES)** is one of 6 components in ACTRIS

- Provides operational services for long-term **harmonized** observations of the atmospheric column and cloud properties through instrument **synergy**

Data handling is performed by a **dedicated data centre unit (CLU)** that operates the **Cloudnet data portal** (https://cloudnet.fmi.fi/)

- CLU performs data versioning, data provision and archiving and also handles the synergistic cloud classification and processing algorithm Cloudnet





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ACTRIS Cloud Remote Sensing (CRS) network

ACTRIS Centre for Cloud Remote Sensing is composed of four Units; operating in France, the Netherlands, Germany and Finland.

CCRES-FR

Unit Head: Martial Haeffelin

Expertise: Doppler Cloud Radar, Disdrometer, Ceilometer

CCRES-NL

Unit Head: Herman Russchenberg

Expertise: Doppler Cloud Radar, Ceilometer

CCRES-DE

Unit Head: Bernhard Pospichal

Expertise: Microwave radiometer

CCRES-FI

Unit Head: Ewan O'Connor

Expertise: Doppler lidar

CRS National Facilities are beneficiaries of CCRES and CLU services : 25 observational platforms and 2 mobile stations

ACTRIS cloud remote sensing network :

- ❑ has good geographical coverage
- ❑ automated data quality controlled and centrally processed
- ❑ cloud radar calibration using reference radar & stability monitoring using disdrometer drop size distributions
- ❑ cloud radar + microwave radiometer + backscatter lidar

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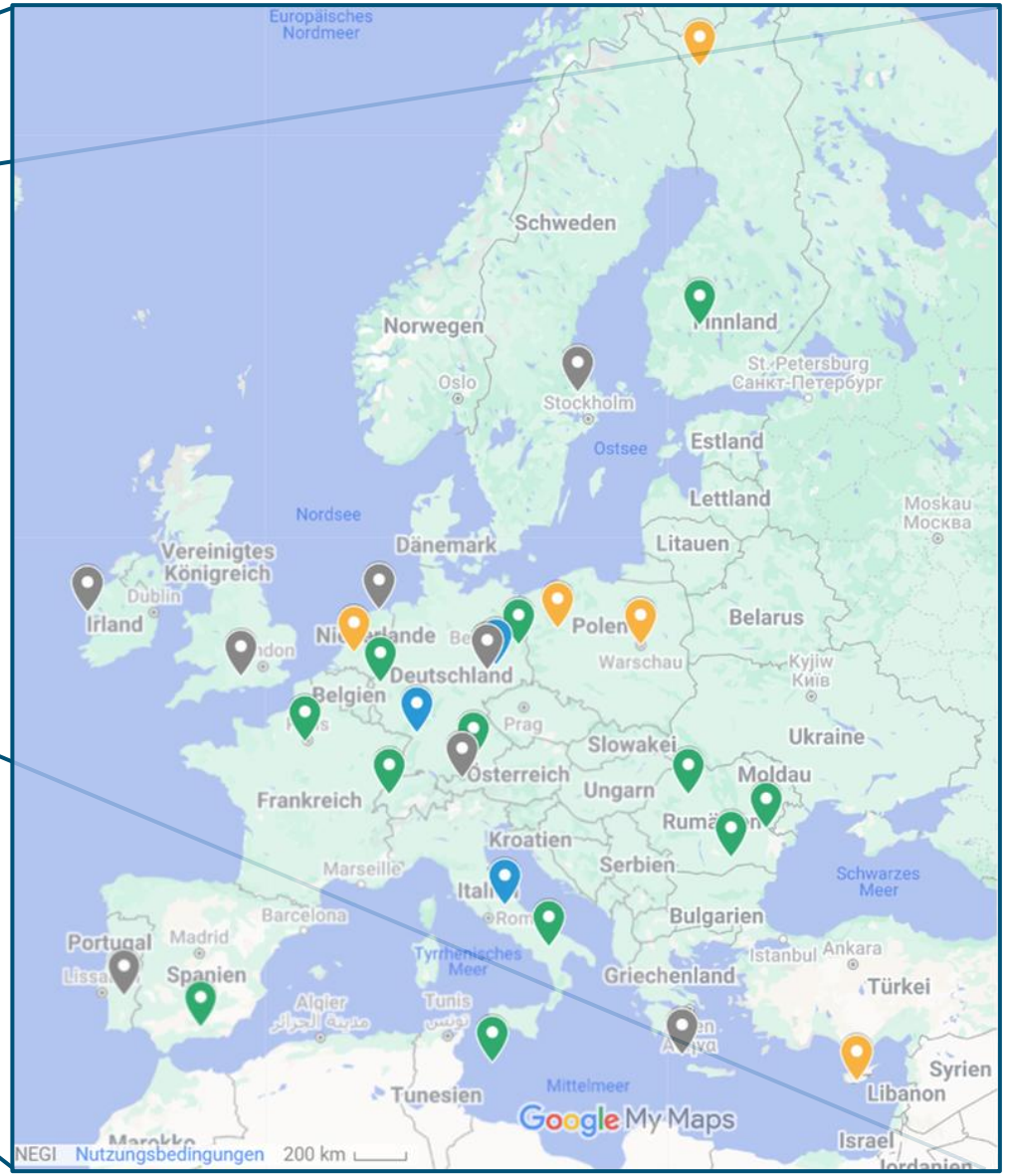
Cloud remote sensing national facilities

~25 National Facilities across Europe and beyond, ~20 currently (nearly) operational

13 NF in Labeling Step1a
5 preparation for labeling
5 Further upcoming ACTRIS NF (incl. mobile)
Non-ACTRIS Cloudnet sites



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CCRES data centre unit CLU

Cloudnet data portal (https://cloudnet.fmi.fi/)

Automated data transfer from NF to CLU

- ❏ Most stations in RRT (< 3 hours)

Immediate QA/QC and processing

- ❏ Synergy to diagnose target type
- ❏ Geophysical cloud products

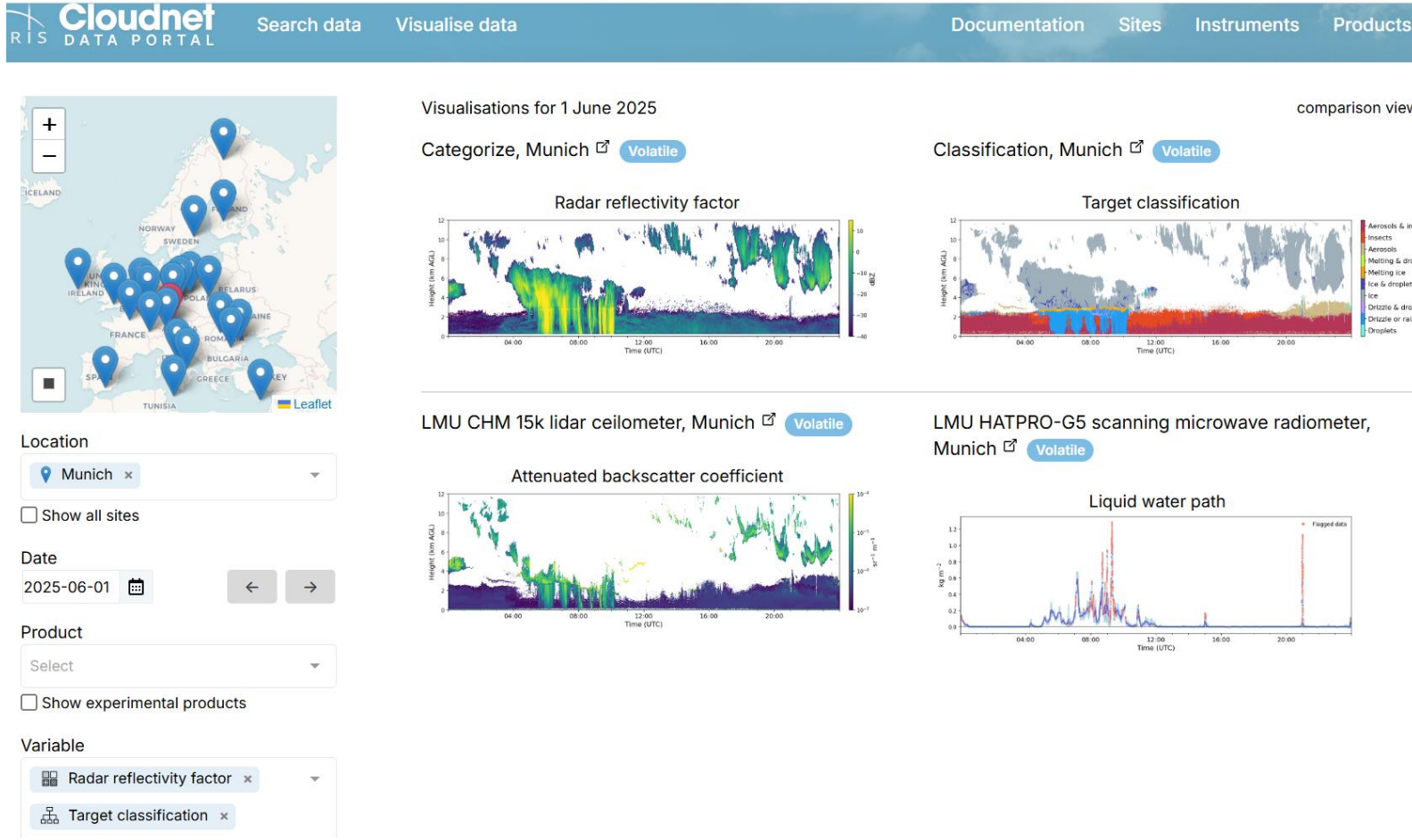
Instrument database

- ❏ Calibration factors
- ❏ Monitoring (-> CCRES)

FAIR data

- ❏ Provenance, versioning, licence
- ❏ Data published with DOI
- ❏ Citation and acknowledgements

APIs to access all services



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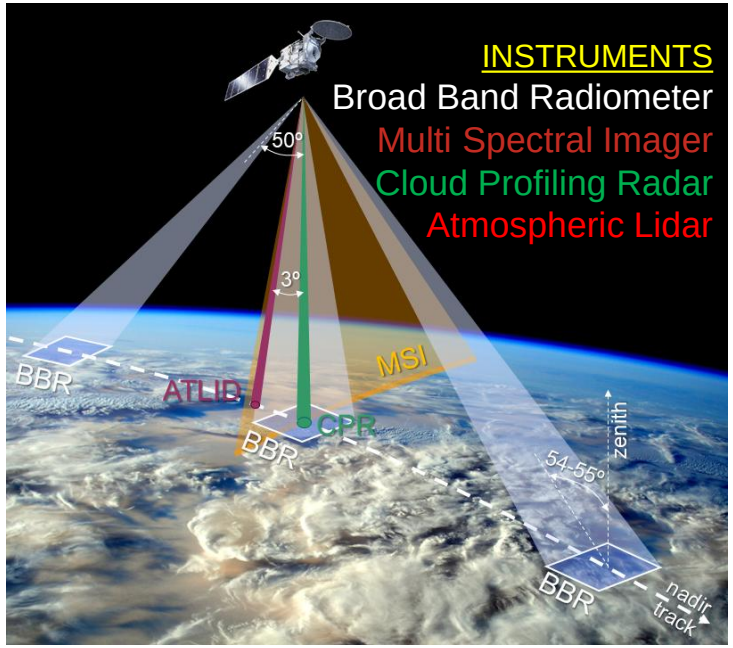
Cal/Val for EarthCARE satellite mission

EarthCARE satellite



- Launched in May 2024
- L1 & L2a data publicly released

EarthCARE = ACTRIS remote sensing from space

ACTRIS Aerosol remote sensing

ACTRIS Aerosol Remote Sensing has also centrally coordinated Cal/Val activities

ACTRIS Cloud remote sensing

- Doppler cloud radars are operated at all sites (35 and/or 94 GHz)
- Common measurement strategy during overpasses

ACTRIS remote sensing network

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Why ACTRIS is a perfect tool for EarthCARE validation:

- 25 fixed sites + mobile facilities → good geographical coverage
- Automated data quality control and central data processing
- ACTRIS Centre for Cloud Remote Sensing → monitoring of data quality
- Cloud radar calibration using a reference radar (Jorquera, 2023)
- Reflectivity monitoring using disdrometers
- Instrumental Synergy: radar + microwave radiometer + backscatter lidar → cloud target classification → EarthCARE L2 cloud product validation

Method: Comparison of data from overpasses within a 150 km radius of the site and ±1 hour zenith-pointing observations (Protat et al., 2010).

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Synthetic EarthCARE CPR data for each ACTRIS site

Geosci. Model Dev., 18, 101–115, 2025
https://doi.org/10.5194/gmd-18-101-2025

Geoscientific Model Development
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Model description paper

Orbital-Radar v1.0.0: a tool to transform suborbital radar observations to synthetic EarthCARE cloud radar data

Lukas Pfitzenmaier[1], Pavlos Kollias[1,2], Nils Risse[1], Imke Schirmacher[1], Bernat Puigdomenech Treserras[3], and Katia Lamer[4]

[1]Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany
[2]School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY, USA
[3]Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, Canada
[4]Environmental and Climate Sciences Department, Brookhaven National Laboratory, Upton, NY, USA

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1 Introduction

Spaceborne radars offer a unique opportunity to monitor clouds and precipitation globally. For instance, the National Aeronautics and Space Administration (NASA) CloudSat Cloud Profiling Radar (CloudSat CPR; Stephens et al., 2008, 2018) enabled several advances in cloud and precipitation physics (Rapp et al., 2013; Stephens et al., 2018; Battaglia et al., 2020b). In 2024, the next-generation CPR in space was launched on board the Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) satellite (Illingworth et al., 2015; Wehr et al., 2023). The EarthCARE CPR is the first Doppler radar in space, thus providing the first set of global Doppler velocity measurements (Kollias et al., 2022). In addition to the Doppler capability, the EarthCARE CPR has higher sensitivity than its predecessor (-35 dBZ vs. -30 dBZ) as well as a smaller footprint (0.8 km vs. 1.4 km) and shorter along-track integration (500 m vs 1.1 km).

Spaceborne radars operate from platforms that orbit the Earth at speeds that exceed 7 km^{-1} and employ relatively long pulses to map the vertical structure of hydrometeors in the atmosphere. The strongest echo a spaceborne radar detects is from the Earth's surface. Instrument simulators are a well-established methodology for accounting for the effects of the observing system sampling geometry on its performance (i.e. detection limit, measurement uncertainty). For example, Lamer et al. (2020) developed an instrument forward simulator to evaluate the impact of different spaceborne CPR configurations on our ability to detect low-level clouds

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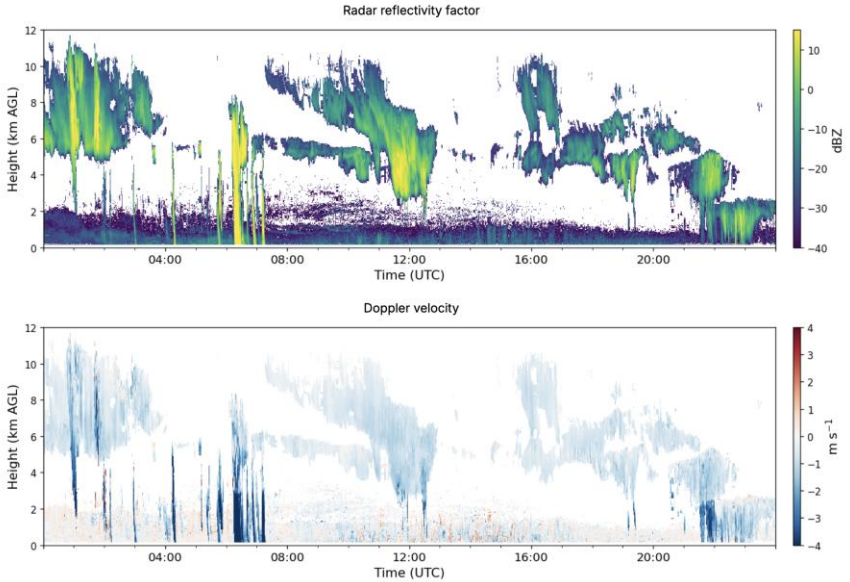
Tool: For validation, a CPR forward simulator was developed to compare ground-based and satellite radar reflectivity and Doppler velocity data.



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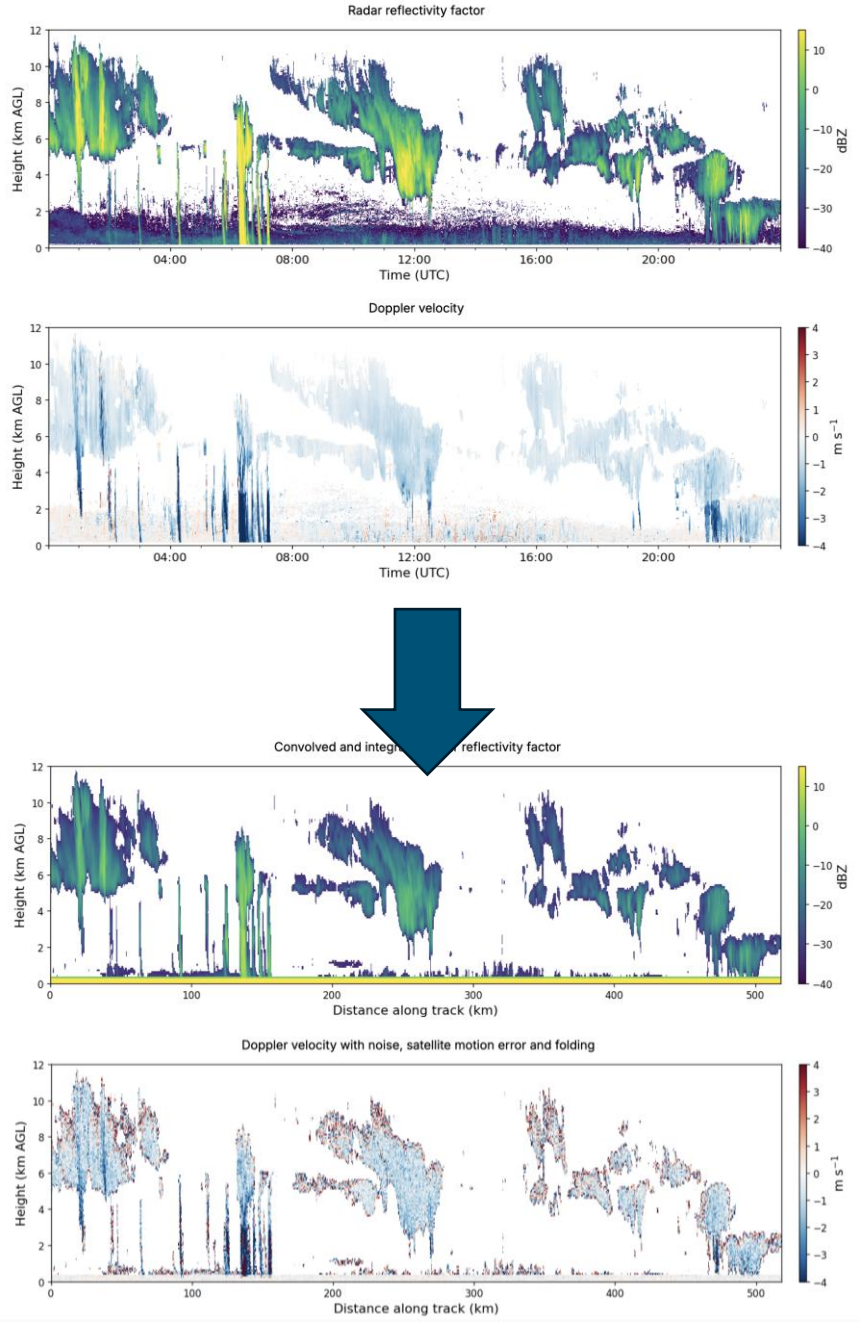

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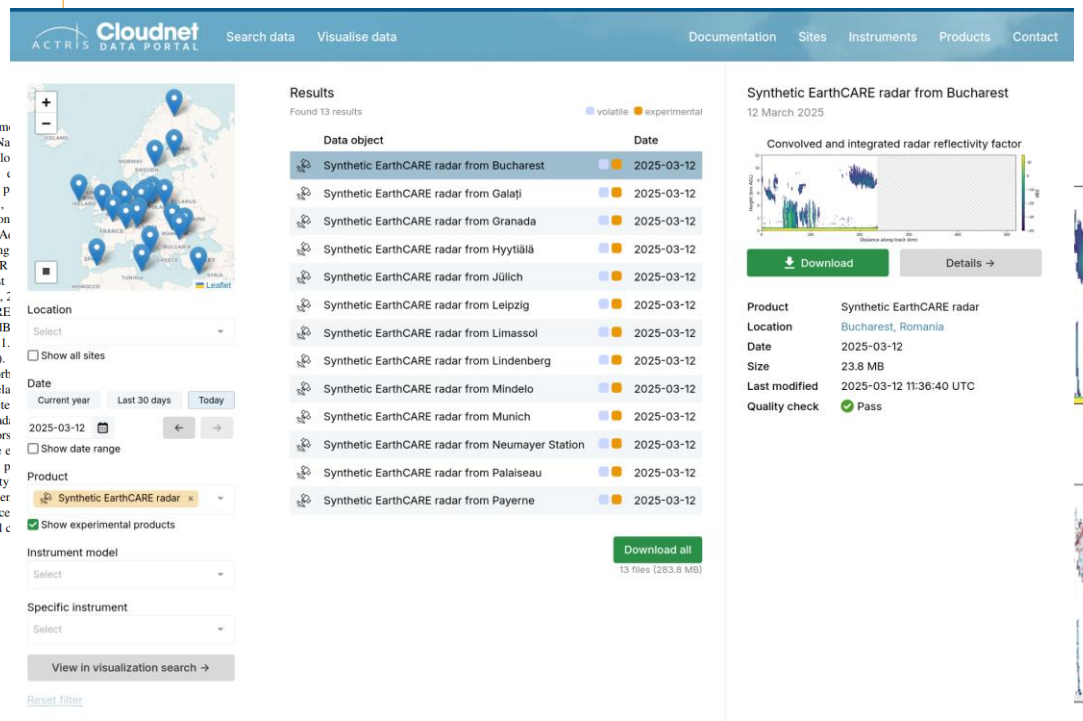

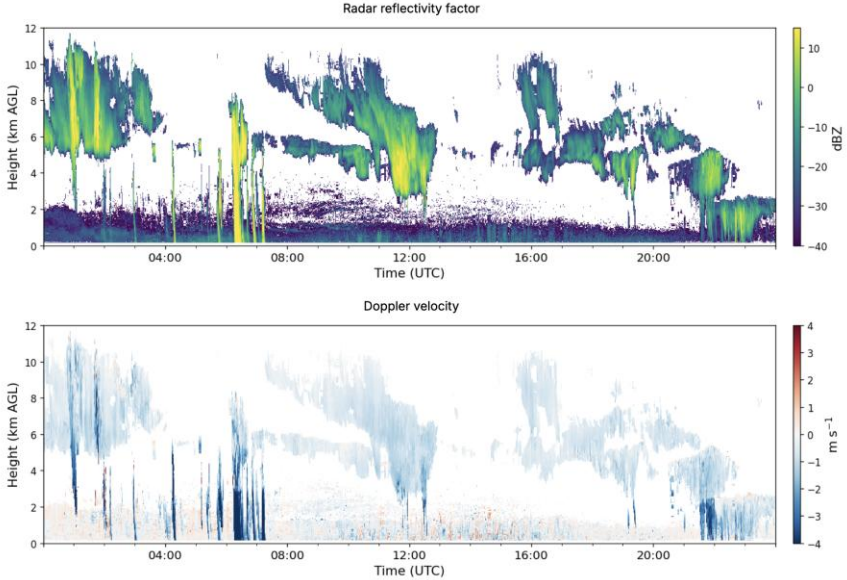

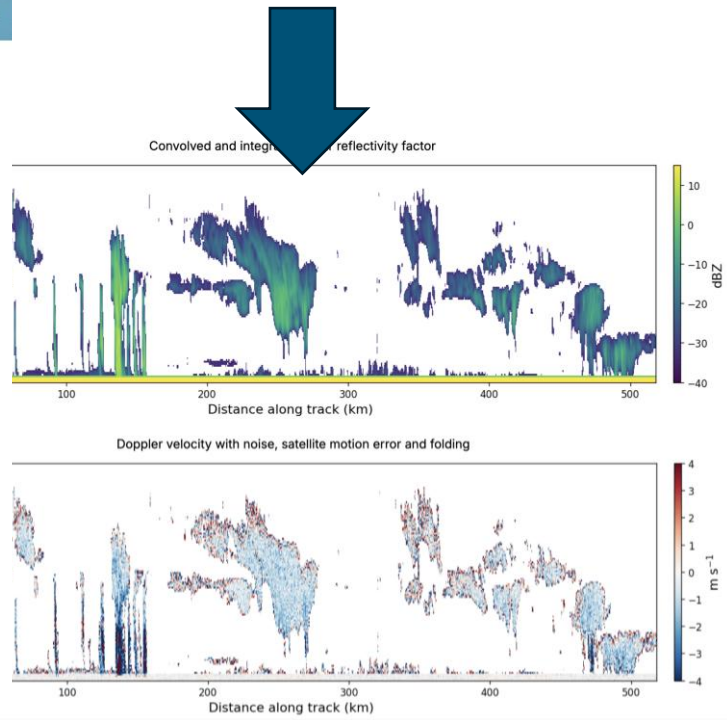

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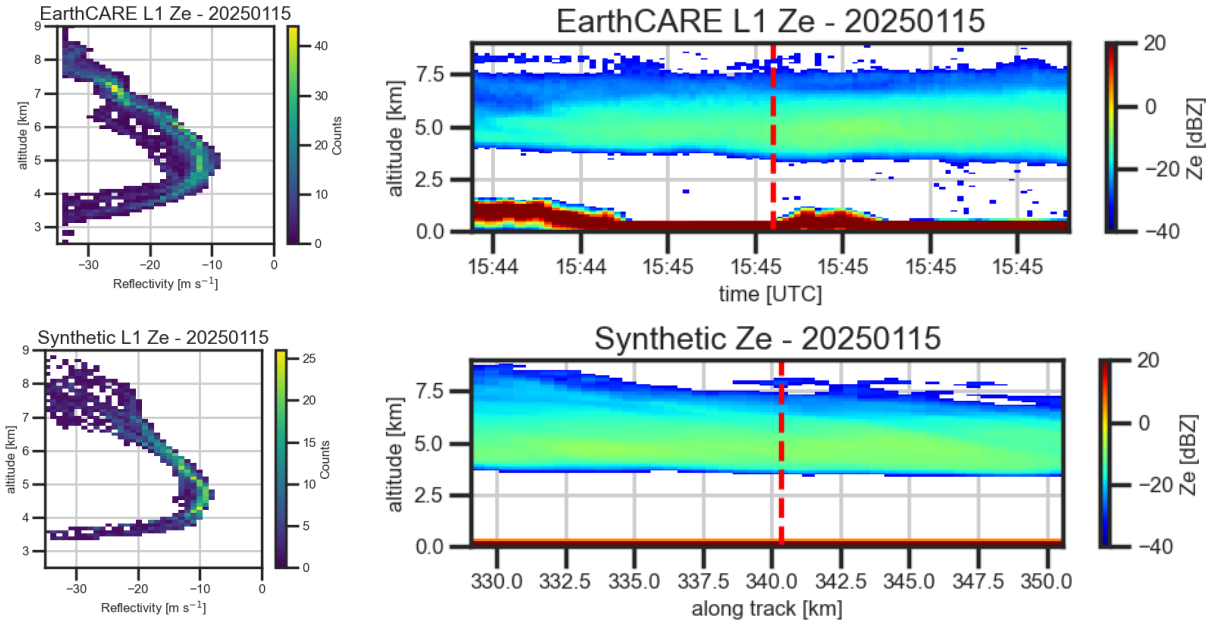
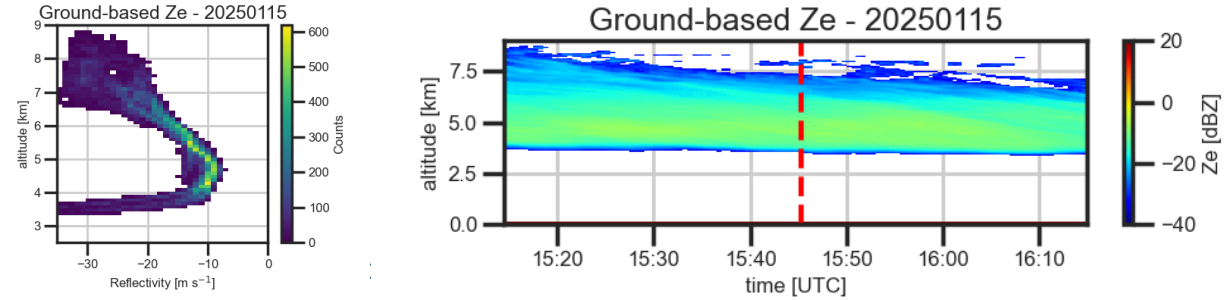
EarthCARE CPR Case Study – NyAlesund 15 January 2025 15:44:48



EarthCARE overpass over the 94 GHz cloud radar at NyÅlesund, 15th January 2025. Plots show data 25 km radius around the site (top) and +/- 30 min around the overpass (bottumn). 94 GHz cloud radar data transformed into synthetic EarthCARE data* (2nd from top). Additional EarthCARE L2 Doppler velocity product (right)

***Pfitzenmaier, L.**, Kollias, P., Risse, N., Schirmacher, I., Puigdomenech Treserras, B., and Lamer, K.: Orbital-Radar v1.0.0: a tool to transform suborbital radar observations to synthetic EarthCARE cloud radar data, Geosci. Model Dev., 18, 101–115, https://doi.org/10.5194/gmd-18-101-2025, 2



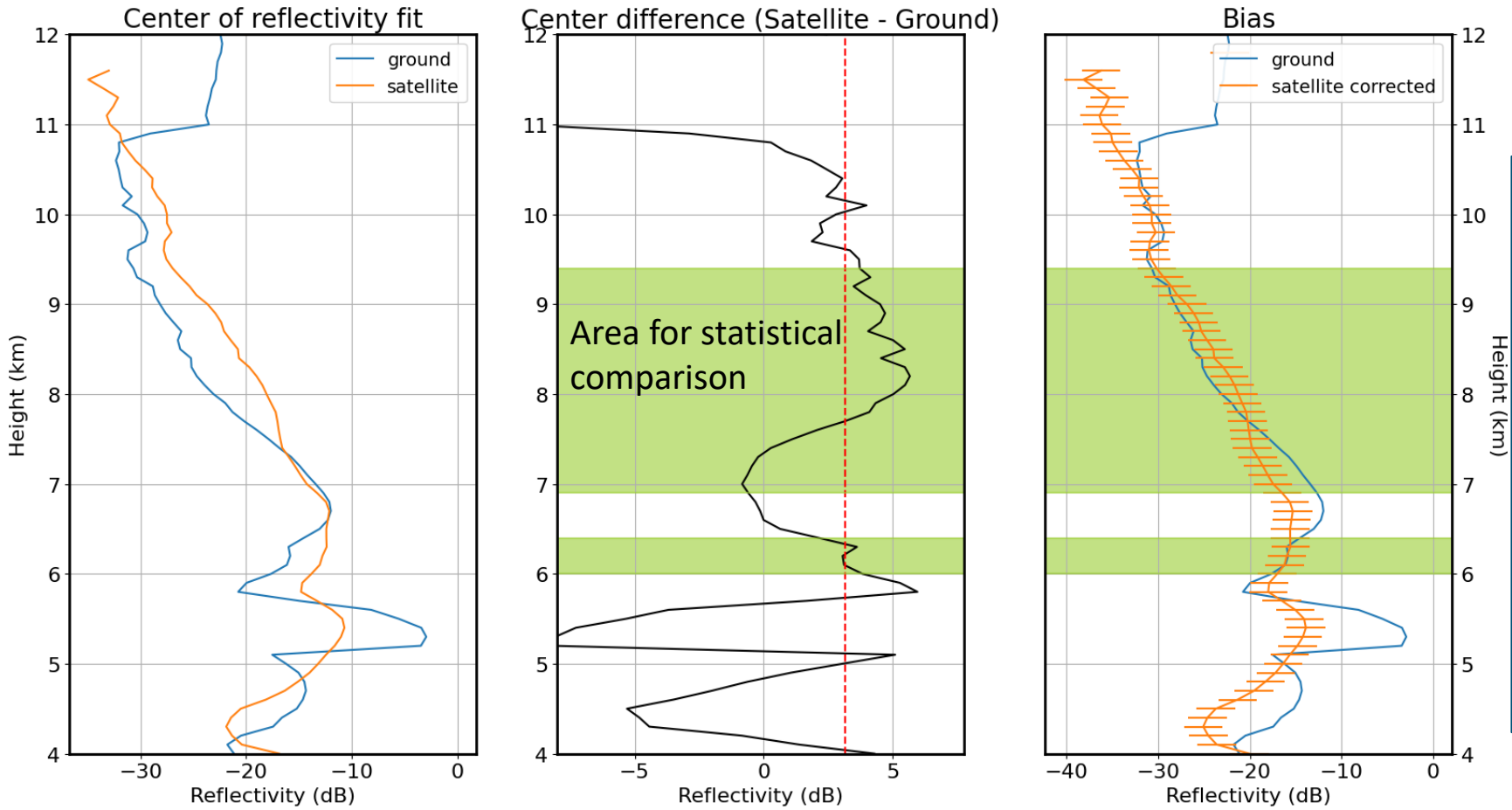
- "golden cals" → very good comparison 1.75 km away from site
- Stratus and no low liquid water clouds → low attenuationg for ground radar
- CPR L1, the synthetical CPR and the ground radar have very good agreement
- Synthetical radar has a better 1 to 1 comparison as the not synthetical CPR data → more effect visible in the Vm data

- With such data sets a direct offset estimation would work!
- BUT not a usual case! → statistical approach!

Statistical validation of CPR Reflectivity vs. ground site

- **Methodology to evaluate the data before the comparison:**
- Fitting a Lorentzian model to the data to test hypothesis´of statistical similarity
- Filtering based on the width, amplitude and distribution mean

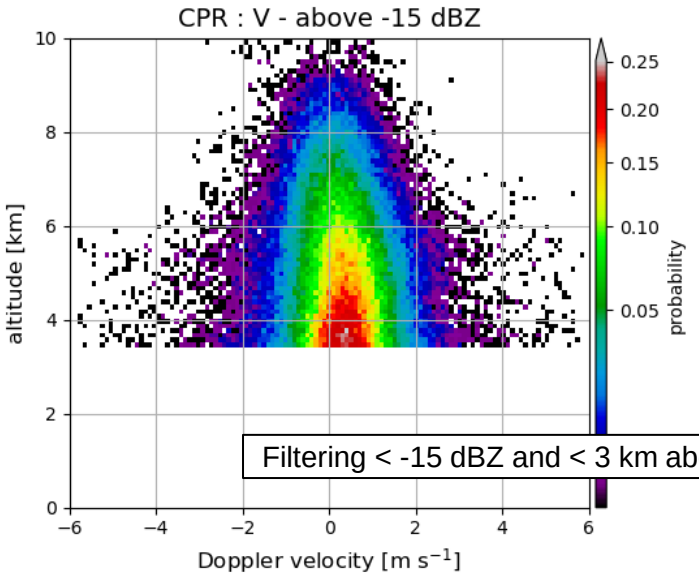
Ze-validation example: Lindenberg, Germany, Baseline CA:



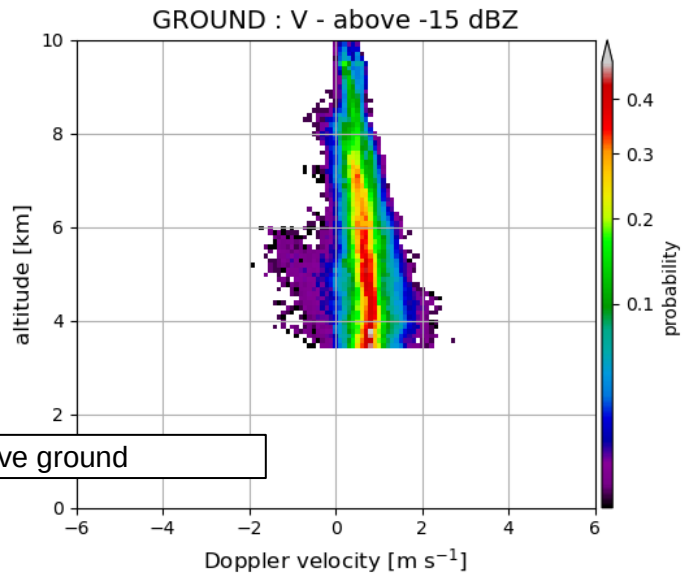
Initial results indicate that the calibration changes of the CPR are evident through the employed method.
Cross-validation of Ze values from CPR and ground-based radars reveals an excellent state of the ACTRIS cloud radar calibration.

Long-term analysis of vertical Doppler velocity (statistics)

Satellite

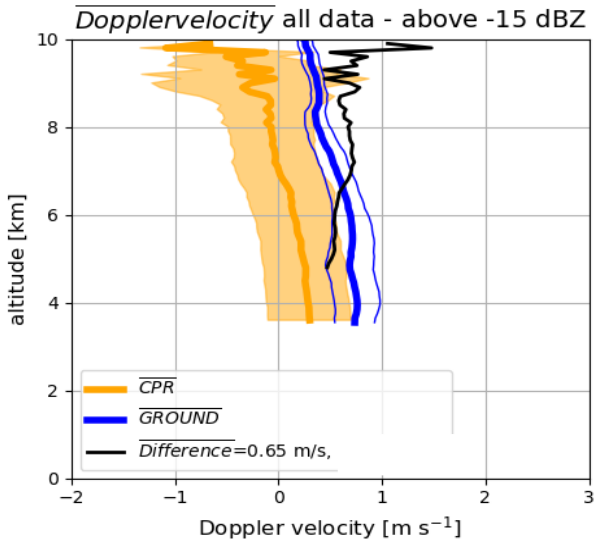


Ground



Filtering < -15 dBZ and < 3 km above ground

mean difference



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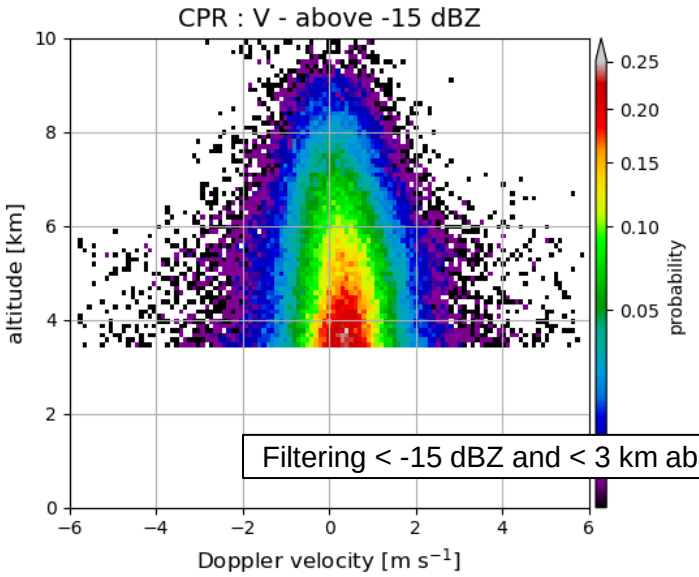

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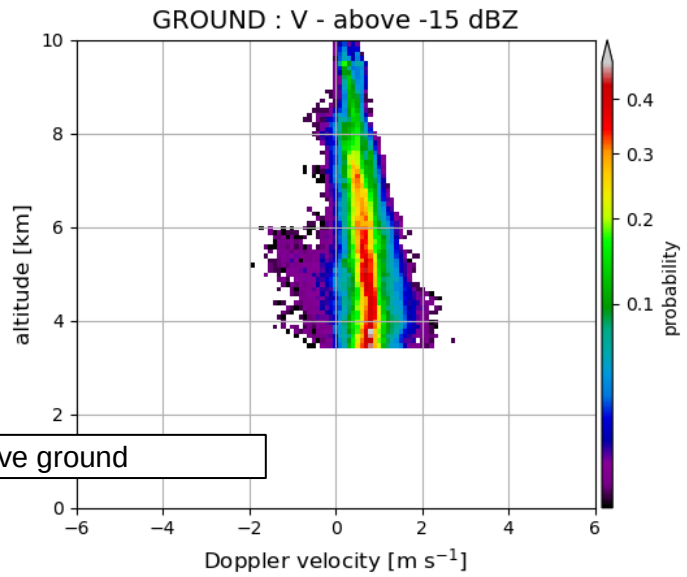

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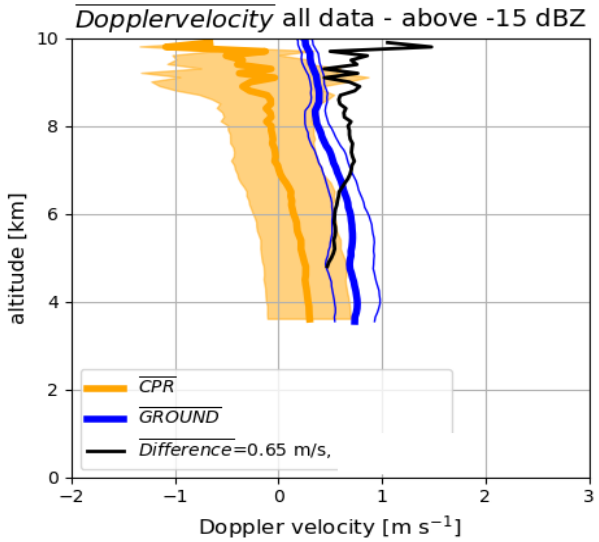

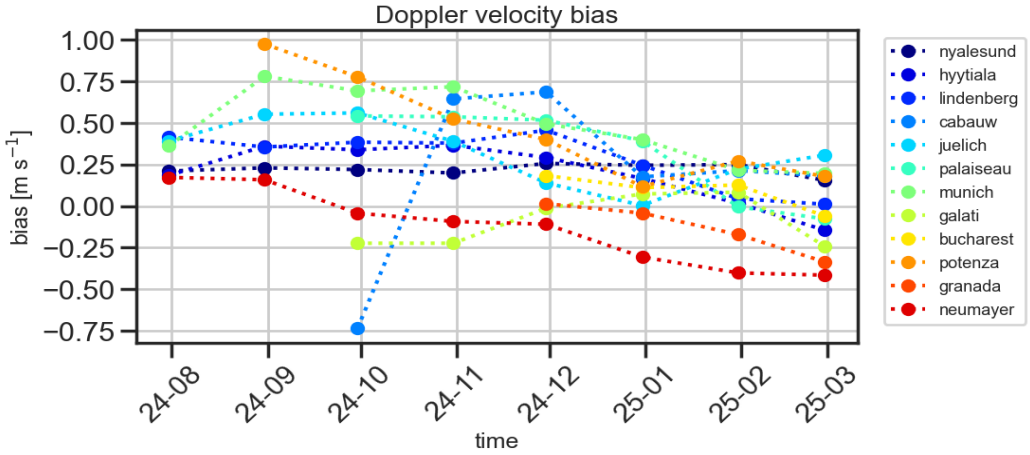

Variation of the Doppler velocity offset with time

CPR antenna miss-pointing causes a **Doppler velocity bias (**depends on the solar radiation hitting the CPR antenna, Puigdomènech Treserras et al., 2025).

→ ACTRIS can validate pointing and its correction

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Results: Doppler velocity validation

Work in progress! Next steps:

- Validate L2a CPR data against ground-based radar data
- Compare our method with other Doppler velocity validation results
- Monitor the ground-based radar pointing

Questions:

- What can we lead from temporal variation of the Doppler velocity offsets in L1?
- Monitoring of the CPR antenna pointing?

North

Number of overpasses

Site	Vm bias (BA)	Vm bias (BB)	Vm bias (CA, 2025)	Vm bias (CA, all)
Ny Ålesund	0.65 ms^{-1}	ms^{-1}	0.14 ms^{-1}	0.17 ms^{-1}
Hyytiälä	0.40 ms^{-1}	0.25 ms^{-1}	0.16 ms^{-1}	0.26 ms^{-1}
Lindenberg	0.59 ms^{-1}	0.43 ms^{-1}	0.06 ms^{-1}	- 0.21 ms^{-1}
Cabauw	0.65 ms^{-1}	0.33 ms^{-1}	0.48 ms^{-1}	0.42 ms^{-1}
Jülich	0.29 ms^{-1}	No enough data	0. 27 ms^{-1}	0.26 ms^{-1}
Palaiseau	0.53 ms^{-1}	0.47 ms^{-1}	- 0.05 ms^{-1}	0.28 ms^{-1}
Munich			0.19 ms^{-1}	0.44 ms^{-1}
Galati	0.49 ms^{-1}	0.34 ms^{-1}	-0.24 ms^{-1}	-0.09 ms^{-1}
Bucharest	0.71 ms^{-1}	0.46 ms^{-1}	0.08 ms^{-1}	0.08 ms^{-1}
Potenza			0.16 ms^{-1}	0.32 ms^{-1}
Granada	0.44 ms^{-1}	ms^{-1}	- 0.34 ms^{-1}	0.01 ms^{-1}
Mindelo	No enough data	No enough data	No enough data	No enough data
Neumayer	0.18 ms^{-1}	0.42 ms^{-1}	0.39 ms^{-1}	- 0.31 ms^{-1}

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Access to CCRES/CLU web-based services

Website	Public	Purpose	Content
ACTRIS EU https://www.actris.eu/topical-centre/ccres	ACTRIS **community**	Link with ACTRIS EU community	General information about ACTRIS and CCRES, communication and events
CCRES Services https://ccres.aeris-data.fr/	Cloud Remote Sensing **National Facilities**	Access to CCRES operational services, technical website (working tool)	Resources and access to CCRES new operational services (SOPs, instrument calibration monitoring, housekeeping data, monthly data quality analyses, documentation on services..) and specific communication on CCRES/CLU services evolution
CloudNet Data Portal https://cloudnet.fmi.fi/	**All CloudNet users** (NFs, Scientists)	Access to data	Data processing and curation service for ground-based cloud remote sensing measurements. Includes CLU services and some CCRES services (e.g. instrument database).

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Summary

- ACTRIS Cloud Remote Sensing Network provides continuous high-quality observations of clouds and their properties
- 15 -> 25 locations in Europe and beyond
- Valuable dataset for studies on cloud microphysics, cloud statistics, model evaluation, parameterization development, satellite validation
- EarthCARE = Cloudnet in space, launched in 2024
- Validation of EarthCARE CPR (radar) shows promising results
- First results show very good calibration status of ground-based radars
- Biases in Doppler velocity need to be further investigated
- Further evaluation of EarthCARE products in progress