ACTRIS CCRES

Three-dimensional cloud analysis during the FLOWER campaign in Spain

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The FLOWER (Flexible Observations of Weather and Cloud Evolution in the Region) Campaign Motivation:

The campaign is part of the national project **CLOUDWATCH** (CLOud Understanding and Tracking for Weather and Climate). The main goal is to retrieve cloud microphysics in 3D, but 3D retrievals from scanning radars rely on strong assumptions on cloud dynamics and its homogeneity, so we must first constrain and validate them in the vertical.

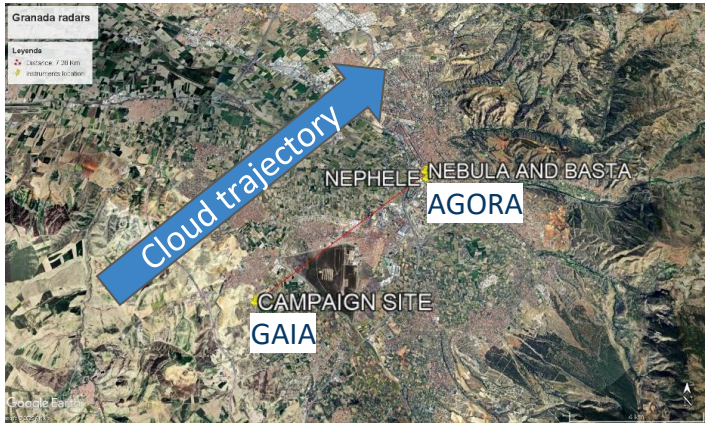
- Start with rain michophysics retrievals with **vertical measurements** (CLOUDWATCH Objective 2: Improve microphysical databases and reduce uncertainties in radar processing).
- Then **scale to 3D using radar scans** (CLOUDWATCH Objective 3: 3D precipitation structures).
- Provides **long-term monitoring of rain michophysics process with MRRPros** (CLOUDWATCH Objective 2: Improve microphysical databases and reduce uncertainties in radar processing)

Objective

- Physically-based PIA estimation for rain-reflectivities of Cloud Doppler Radars (CDR) and mean mass weighted diameter estimation through Dual-wavelength-ratio (DWR) method.
- Assess consistency of rain microphysics between RaProM-Pro (MRRPro) and DWR (dual-frequency radar) microphysical.
- 3D reconstruction of the reflectivity field of 94GHz CDR observations

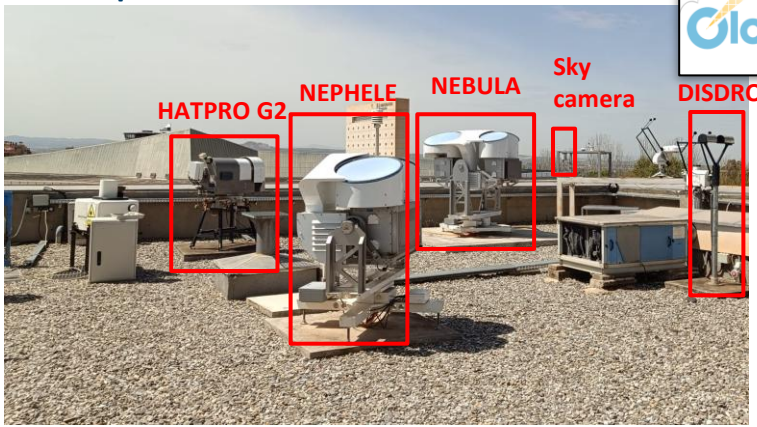
The FLOWER (Flexible Observations of Weather and Cloud Evolution in the Region) campaign

Experimental sites:



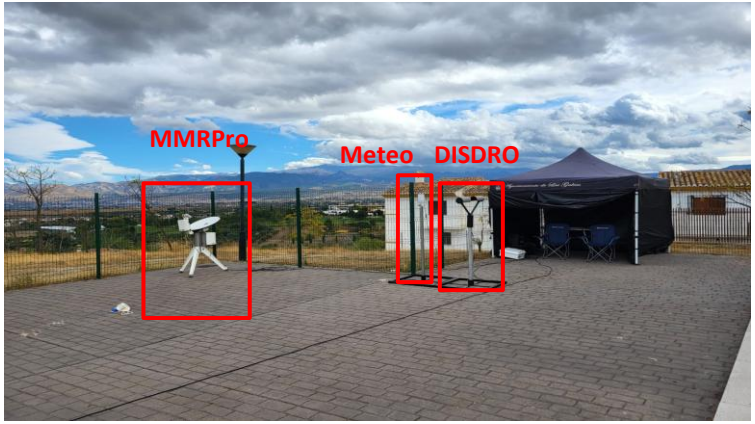
- GAIA is 10 km distance from AGORA
- GAIA is along the cloud trajectories
- 29th of October, 2025, from 13:00 to 15:00h

AGORA: Andalusian Global ObseRvatory of the Atmosphere



- RPG 94 / 35 GHz CDR (NEBULA)
- HATPRO - G2 and G5
- RPG 94 GHz CDR (NEPHELE)
- Disdrometer Parsivel OTT2
- Sky camera
- CHM15k Nimbus Ceilometer

GAIA: GAbIAs station (campaign site)

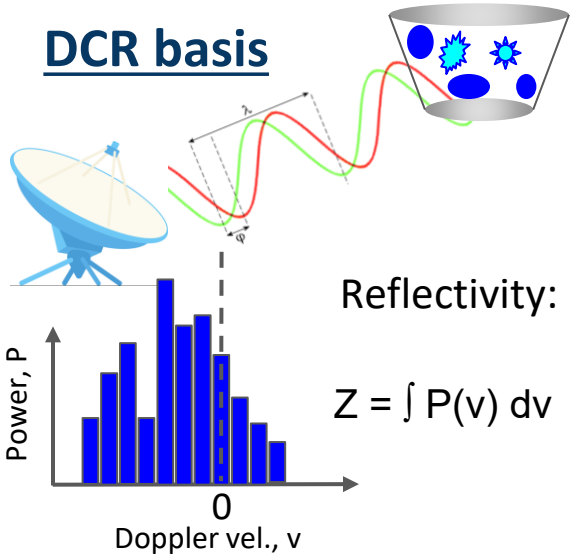


- Meteo
- Disdrometer Parsivel OTT2
- MRRPRO (Metek)

Instruments used in this study

Instrumentation

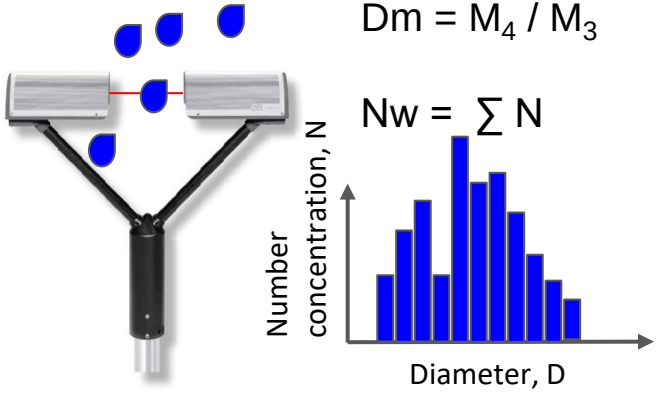
DCR basis



Reflectivity:

$Z = \int P(v)\, dv$

Disdrometer basis



$Dm = M_4 / M_3$

$Nw = \sum N$

MRRPro basis

Same as DCR, but with a different frequency (see table below)

Parameters	Dual frequency DCR		Disdrometer	MRRPro	ECMWF
Frequency	94 GHz	35 GHz		24	Radar frequency
Time	3.6 s	Same	1 min	10	1 hour
Range	25.6 - 37.7 m	Same	-	35	1 km
Variable	Doppler vel. spectrum (DVS)	Same	Droplet size distribution (DSD)	Doppler vel. spectrum (DVS)	-
Products	Reflectivity (Z) in dBZ	Same	Dm (mm), Nw (m-3 mm -1)	Reflectivity (Z) in dBz	Gas PIA

Methods

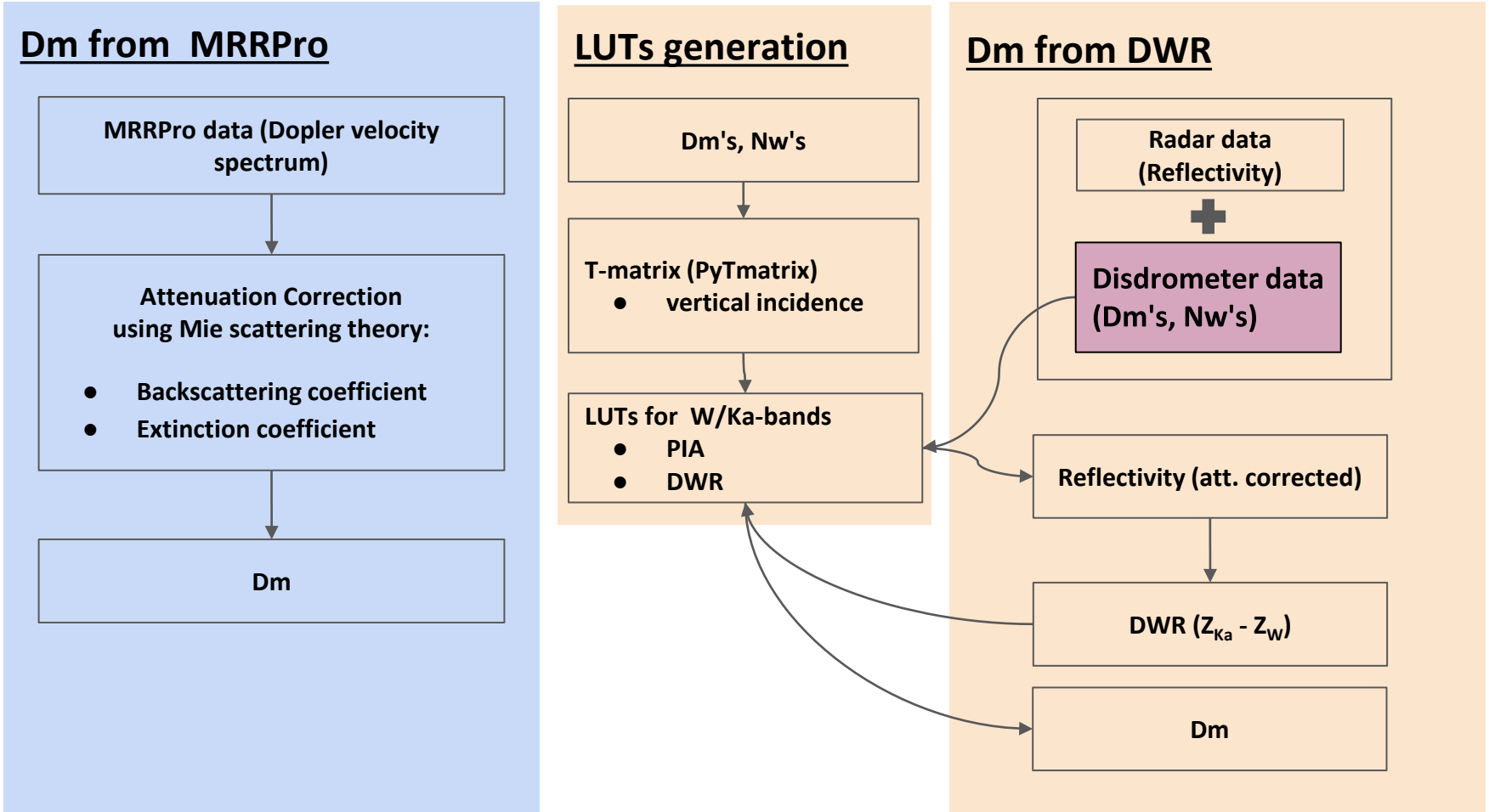
MMRPro:

- **Rain microphysics with MRRPro:** Mean mass weighted diameter (Dm) (García Benedí et al., 2021, https://github.com/AlbertGBena/RaProM-Pro.

Dual-frequency DCR:

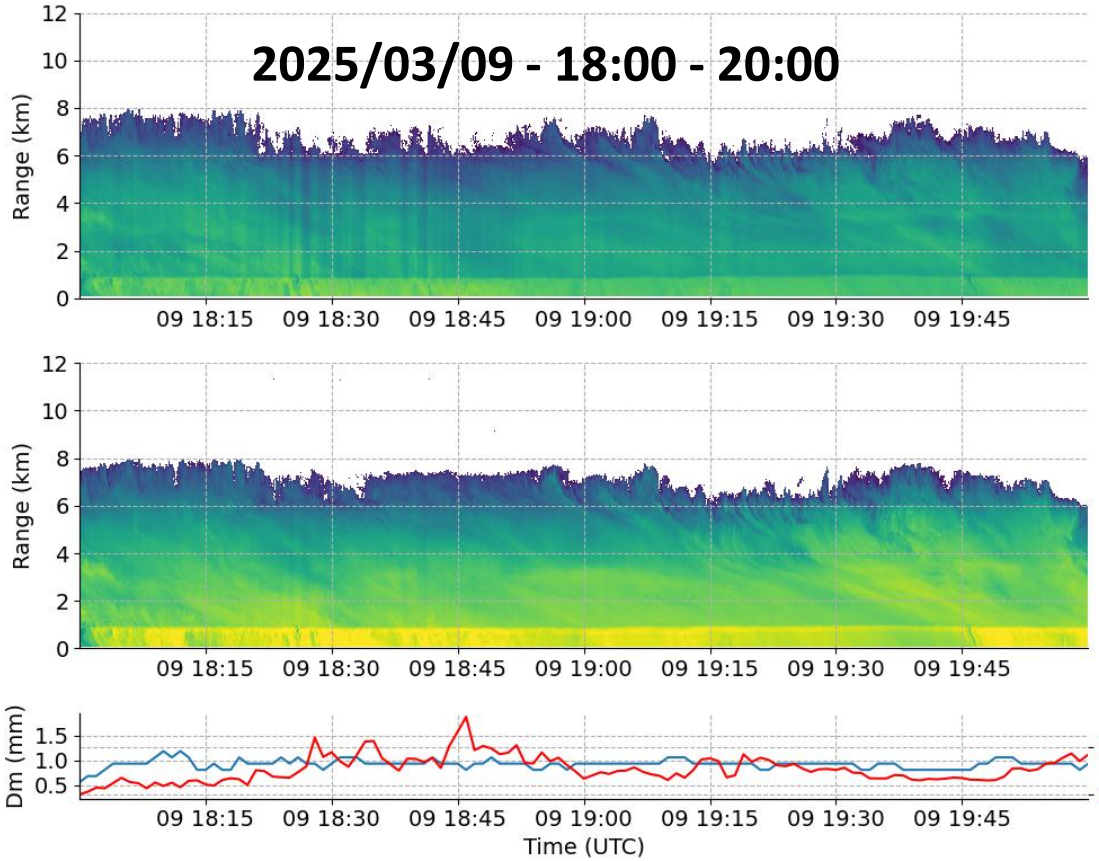
- **Rain microphysics with Dual frequency DCR:** Rain path integrated attenuation (PIA) and mean mass weighted diameter (Dm) with look-up tables (LUTs)
  - T-matrix was used to calculate theoretical functions (Tetoni et al., 2022) of attenuation coefficient vs Dm, and DWR (Z_{Ka} - Z_W) vs Dm.
- **3D cloud reconstruction with reflectivity field:** barycentric interpolation of S-PPI scans observations

Methods


Dm from MRRPro
MRRPro data (Dopler velocity spectrum)
Attenuation Correction using Mie scattering theory:
Backscattering coefficient
Extinction coefficient
Dm
LUTs generation
Dm's, Nw's
T-matrix (PyTmatrix)
vertical incidence
LUTs for W/Ka-bands
PIA
DWR
Dm from DWR
Radar data (Reflectivity)
Disdrometer data (Dm's, Nw's)
Reflectivity (att. corrected)
DWR (Z_{Ka} - Z_W)
Dm

Rain microphysics with Dual frequency DCR (AGORA station)

DWR method: (1) Dataset to PIA estimation and Reflectivity correction



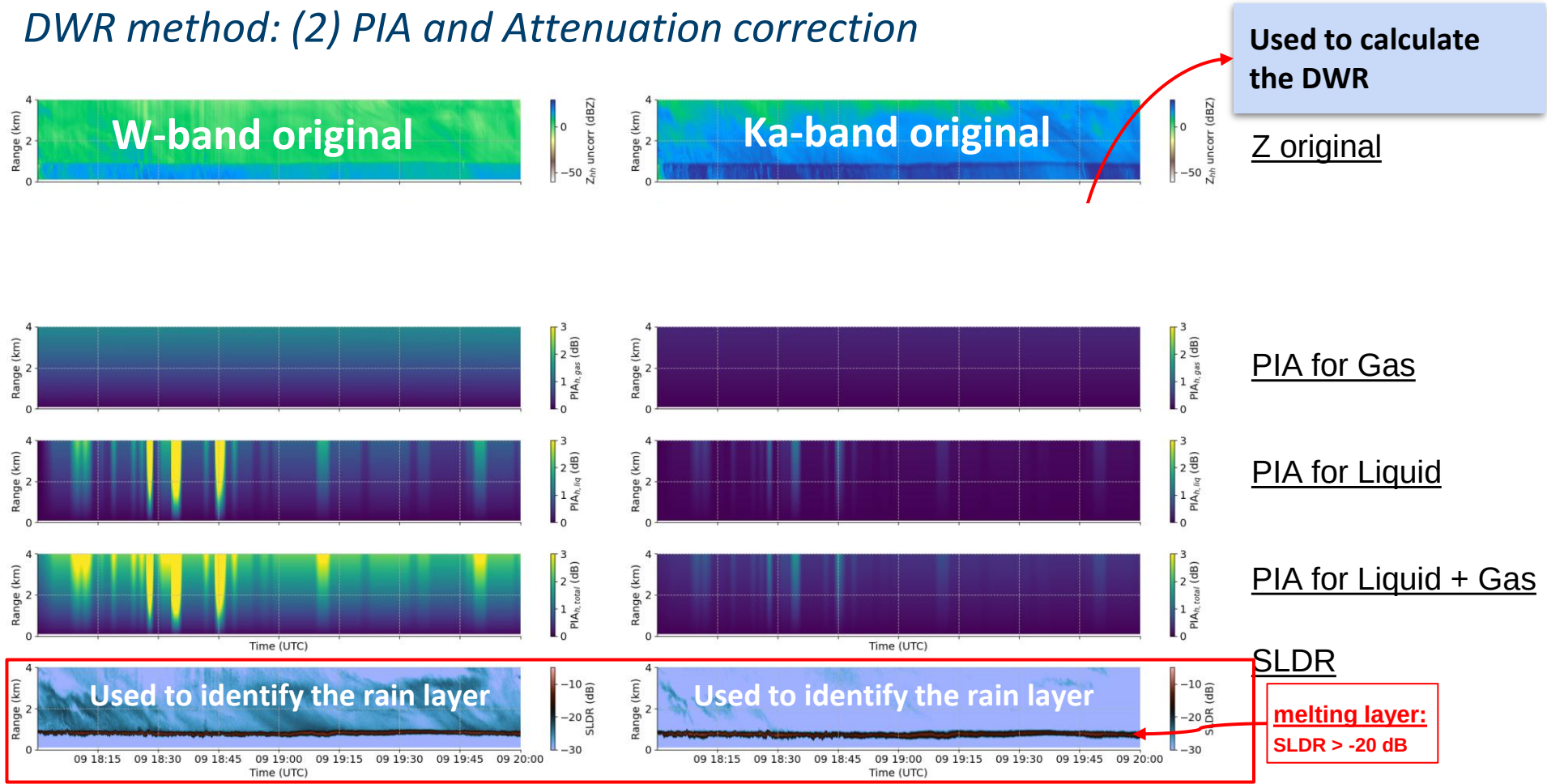
Original reflectivity (W -band)

Original reflectivity (Ka -band)

Dm and Nw from disdrometer: These parameters are used to obtain the PIA using LUTs for rain droplets

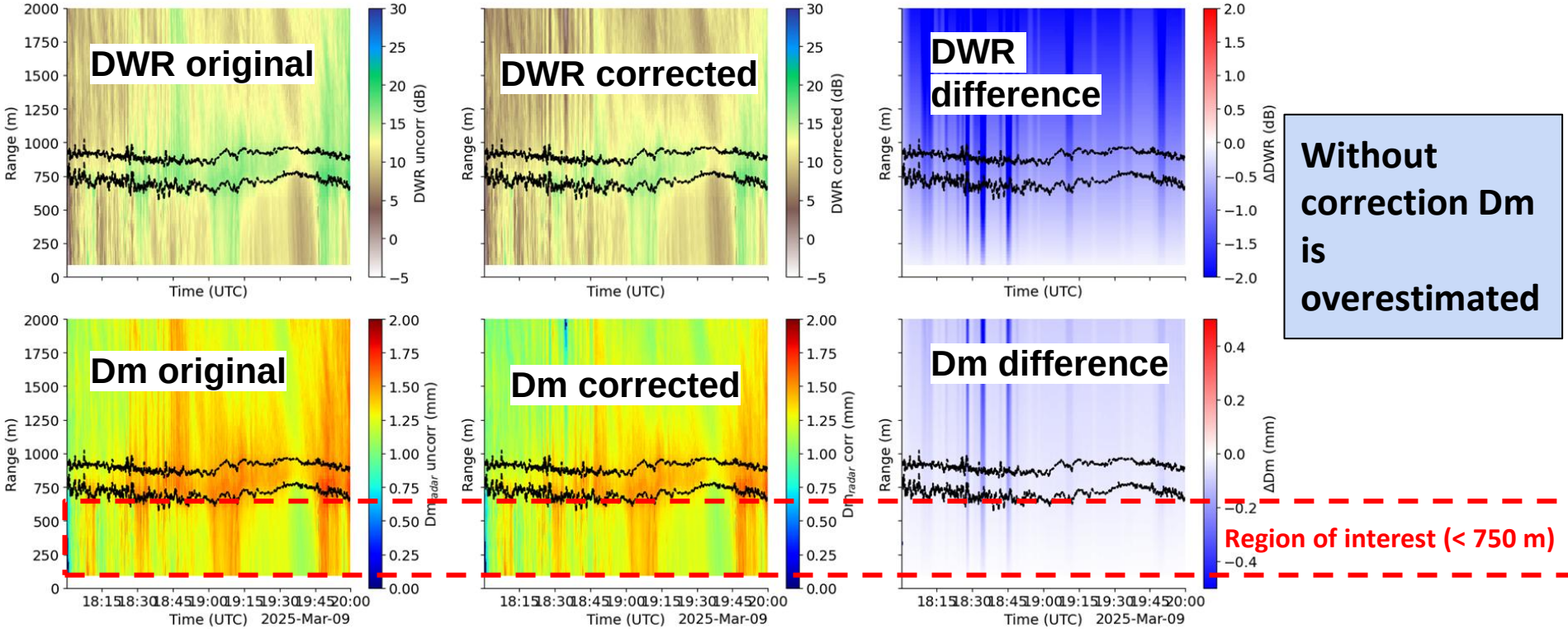
Rain microphysics with Dual frequency DCR (AGORA station)

DWR method: (2) PIA and Attenuation correction



Rain microphysics with Dual frequency DCR (AGORA station)

DWR method: (3) Mean mass weighted diameter retrieval

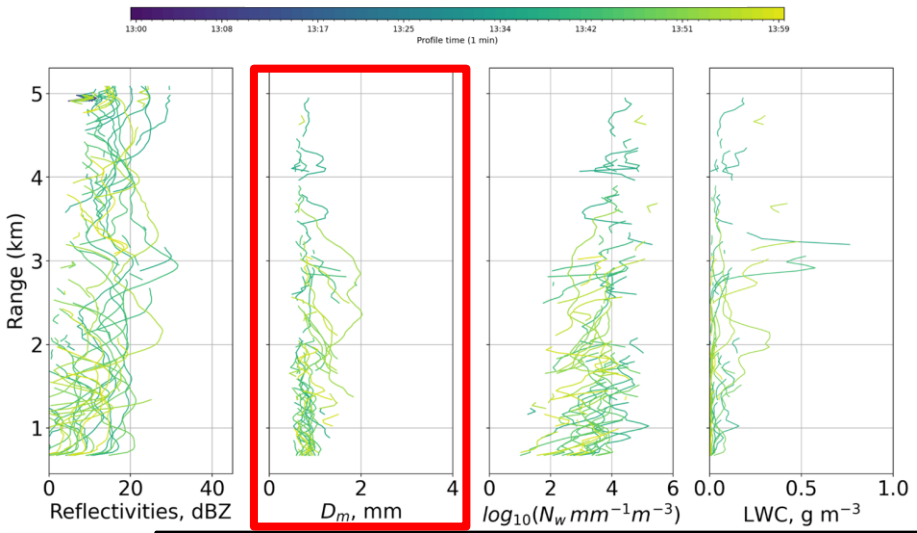


Rain microphysics with MRRPRO (GAIA station)

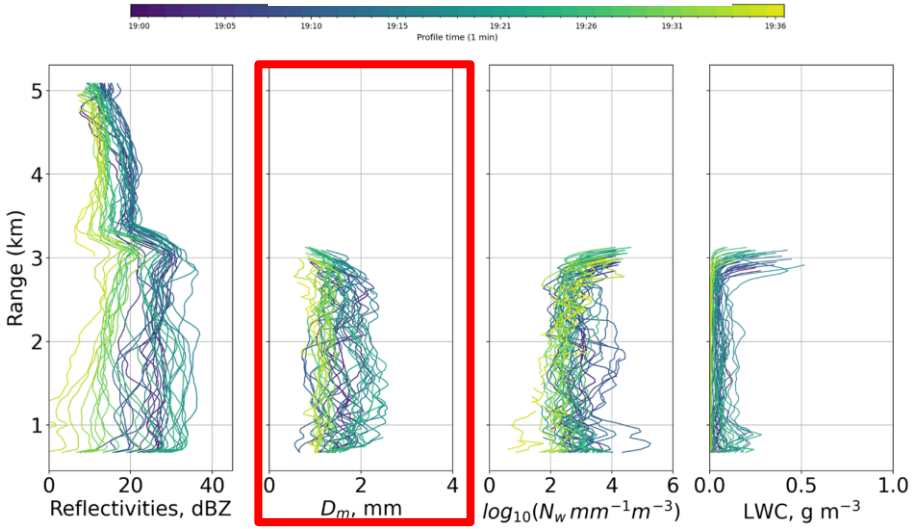
Benedí et al., 2021 method: Mean mass weighted diameter retrieval

Microphysics obtained by RaProM-Pro python algorithm, which includes attenuation correction for Reflectivities (https://github.com/AlbertGBena/RaProM-Pro)

2025/10/29 - 13:44 - 13:51

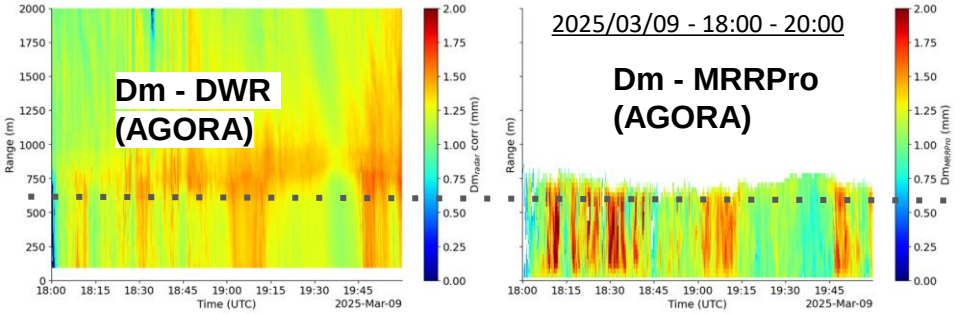


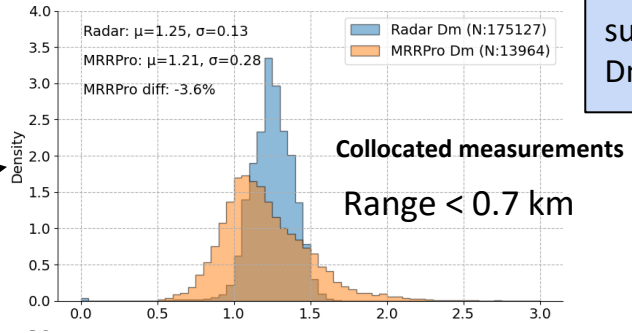
2025/10/29 - 19:10 - 19:18



These two time series will be compared with the DWR method (radar data)

Rain microphysics comparison: DWR vs MRRPro



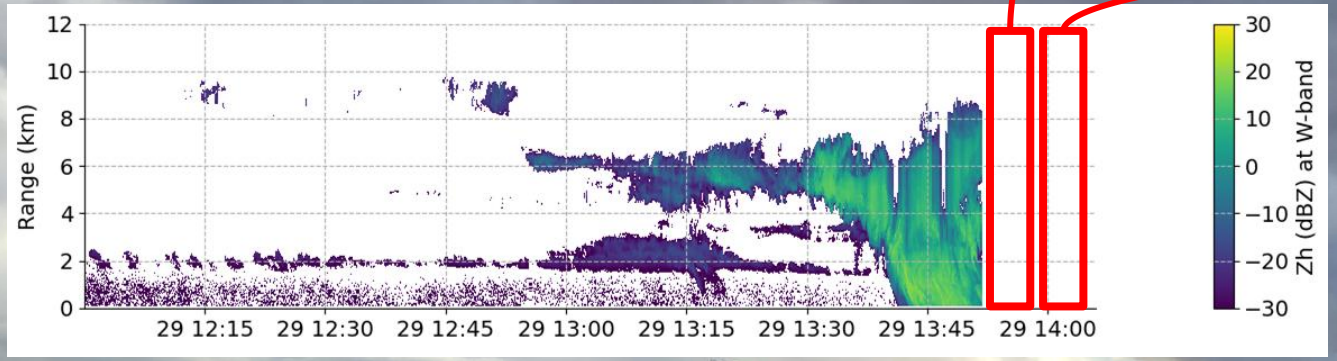


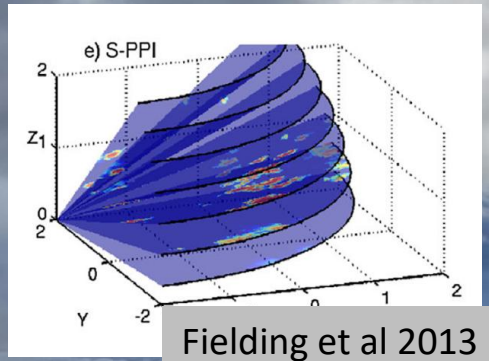
MRRPro superestimates Dm

3D cloud reconstruction

360 PPI for wind retrieval

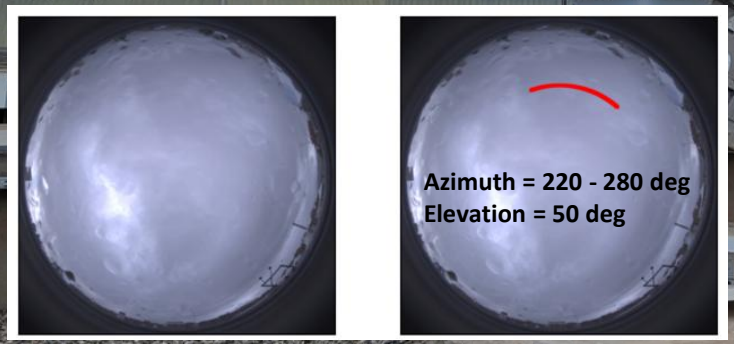
S-PPI for cloud reconstruction





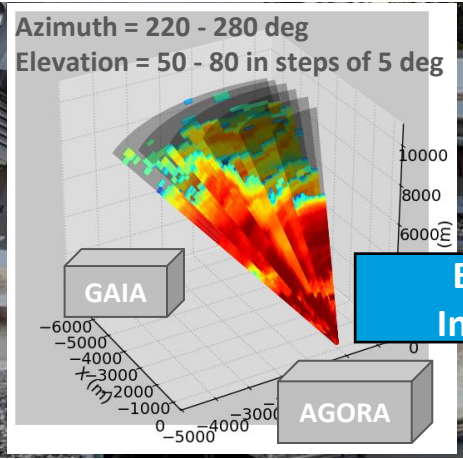
Fielding et al 2013

Sky Camera Image

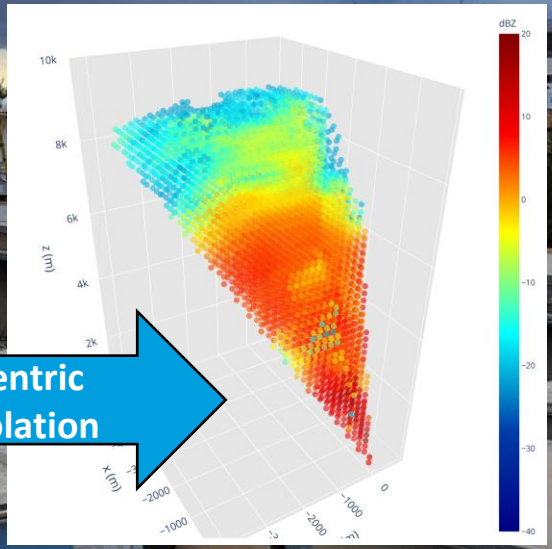


Scans trajectory tracking with Sky camera

NEBULA 94 GHz S-PPIs:



Barycentric Interpolation



Summary and further work

- PIA estimated for rain droplets
- Dm retrieval with DWR implemented
- Consistent Mean Dm between MRRPro and DWR method
- 3D reconstruction of reflectivity field implemented for scanning measurements

<u>Future work:</u>

- PIA for slanted measurements (Attenuation correction for cloud **droplets**, **rain**, **ice** and **melting layer**)

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Thank you