# Investigating the role of ice for the evolution of precipitation using multi-wavelength radar measurements

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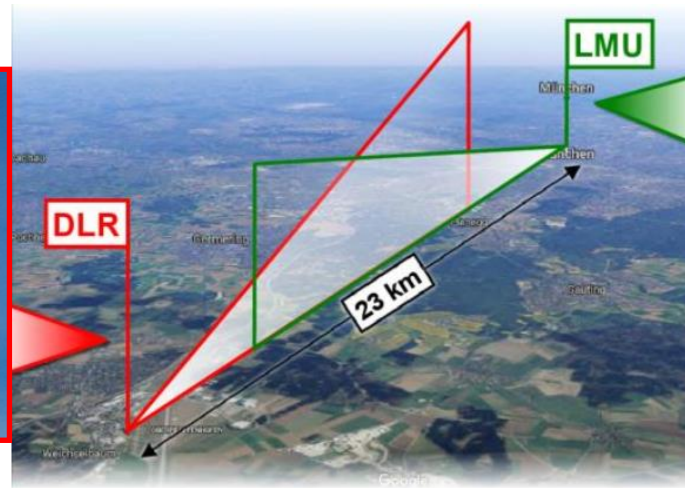
# IcePolCKa:
## The project

- Synergy of two full polarimetric radars, POLDIRAD at DLR, Oberpfaffenhofen and MIRA35 at LMU, Munich.
- Studying the convective initiation and the ice particle growth as well as its role in precipitation formation.
- Contribution from a cloud radar to the Deutscher Wetterdienst (DWD) radar network.
- Numerical modeling using a WRF high-resolution weather model setup to analyze the performance of microphysics parameterizations.

*__I__nvestigation of the initiation of __c__onvection and the __e__volution of __p__recipitation using simulati__o__ns and po__l__arimetric radar observations at __C__- and __Ka__-band*
*Contribution to Priority Programme SPP 2115: Polarimetric Radar Observations meet Atmospheric Modelling (PROM)*

# IcePolCKa:

## The instruments




| POLDIRAD |
| --- |
| C-band Weather Radar (5.5GHz, 250kW) |
| DLR, Oberpfaffenhofen |
| Range res: 150m, Range max.: 125km |
| 4.5m antenna with 1° beam width |
| Full polarimetric (ZDR, KDP etc.) |

| miraMACS (Mira35) |
| --- |
| Millimeter Cloud Radar (35GHz, 30kW) |
| LMU, Munich |
| Range res: 30m, Range max.: 30km |
| 1m antenna with 0.6° beam width |
| Linear Depolarization Ratio (LDR) |

# IcePolCKa:
## My role in the project:

- Through the course of this project, a continuous scan strategy has been operational during precipitation events. POLDIRAD and Mira35 performed RHI scans towards each other (*on axis scans*) every 10 minutes for stratiform precipitation events.

- For convective precipitation, Gregor Möller, Florian Ewald and I, developed scripts for performing RHI scans from both radars at the same time towards interesting precipitation cells (*off axis scans*).

- Both type of measurements produced a dataset to retrieve ice particle microphysical properties and estimate fall speeds from DWR measurements. More RHI scans will be added to this dataset after POLDIRAD returns from Barbados where it will operate during the EUREC4A campaign.

# IcePolCKa:
## Current studies:

- First attempts for estimation of the size as well as the shape and/or the density of the ice particles using Dual – Wavelength measurements from POLDIRAD and Mira35 will be shown in this presentation.

- The Dual – Wavelength measurements from POLDIRAD and Mira35 will be used along with T-matrix simulations for:

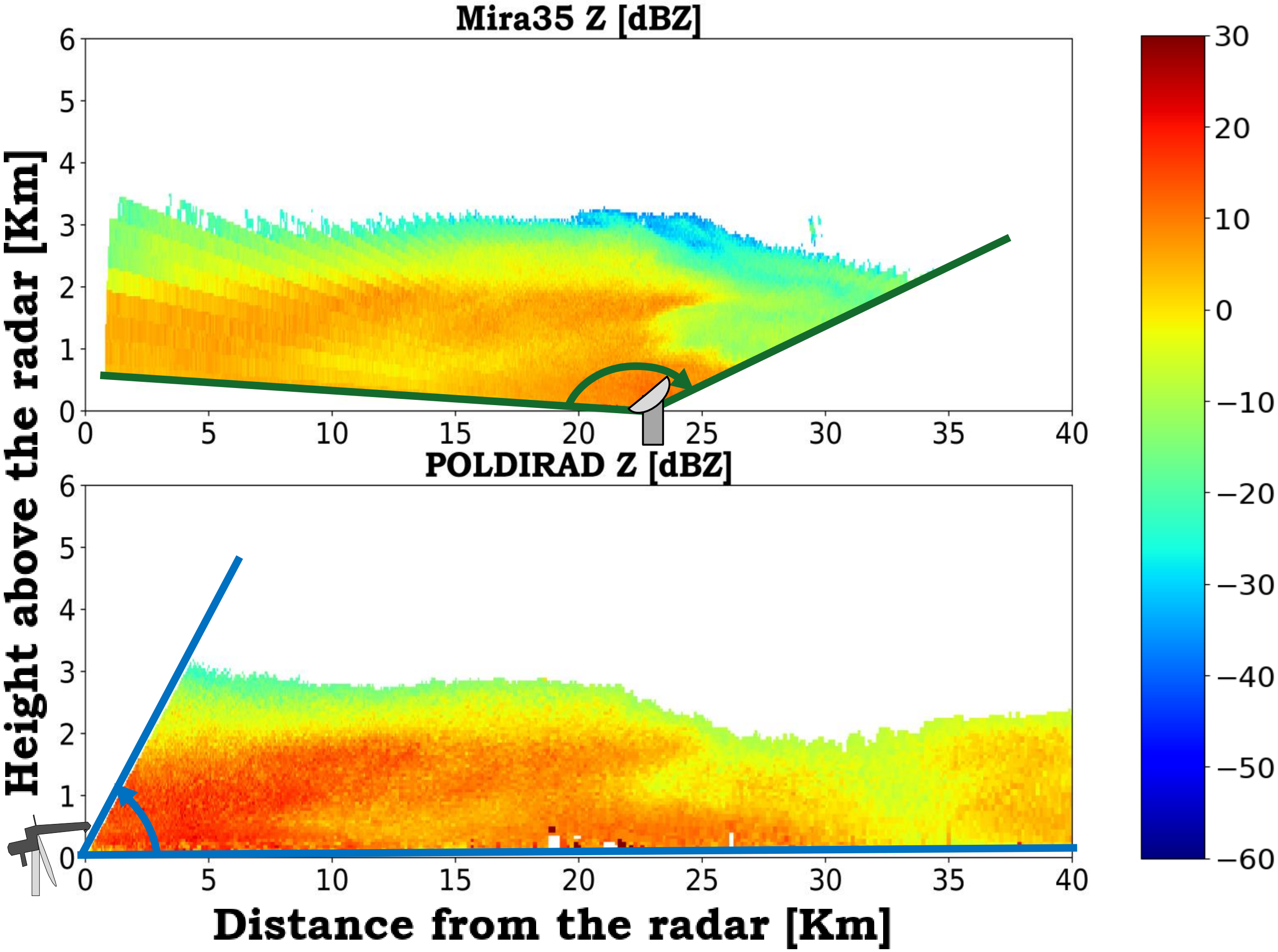
  - constant density for particles that follow Gamma distribution
  - density that changes with the size of particles that follow Gamma distribution, using a Mass-Size relation

- 4 days of continuous - every 10 min - on axis RHI scans were used

- Only ice clouds were studied so that we avoid effects of attenuation from Mira35 Cloud Radar.

# Measurements:

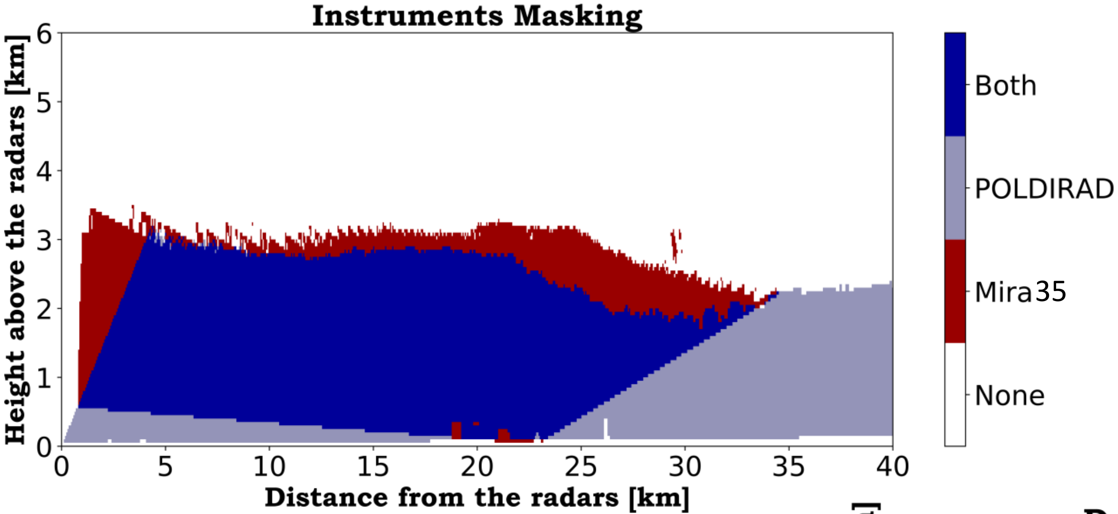
## Example from 2019.01.10 14:38 UTC - On axis RHI scans




Perfectly aligned POLDIRAD and Mira35 performed simultaneously RHI scans towards each other.

# Measurements:

## Example from 2019.01.10 14:38 UTC - On axis RHI scans

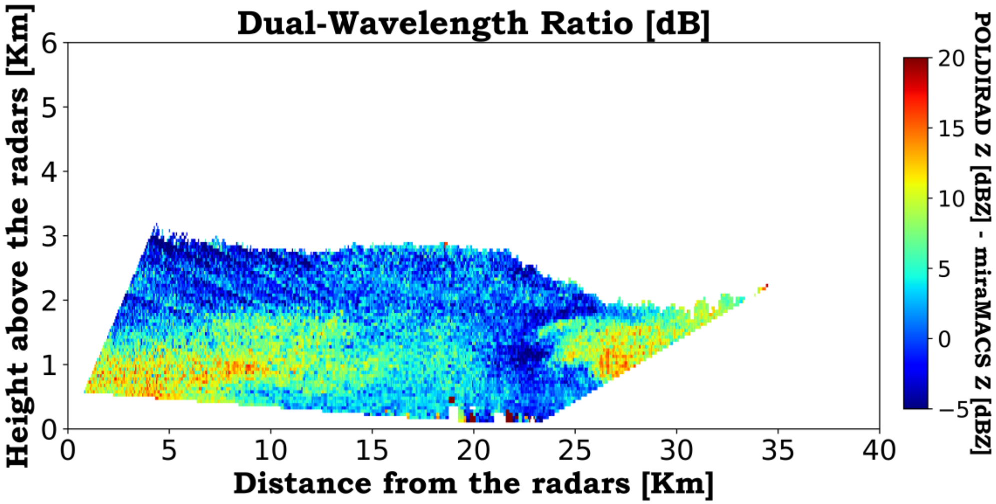



**Dual – Wavelength Ratio (DWR)**

$$DWR = dBZ_{5.5} - dBZ_{35}$$

Calculation of the Dual – Wavelength Ratio from the Radar Reflectivities and selection of profiles where precipitation cells may occur.

Both Radar Reflectivities are projected in the same grid for the area between the two instruments.

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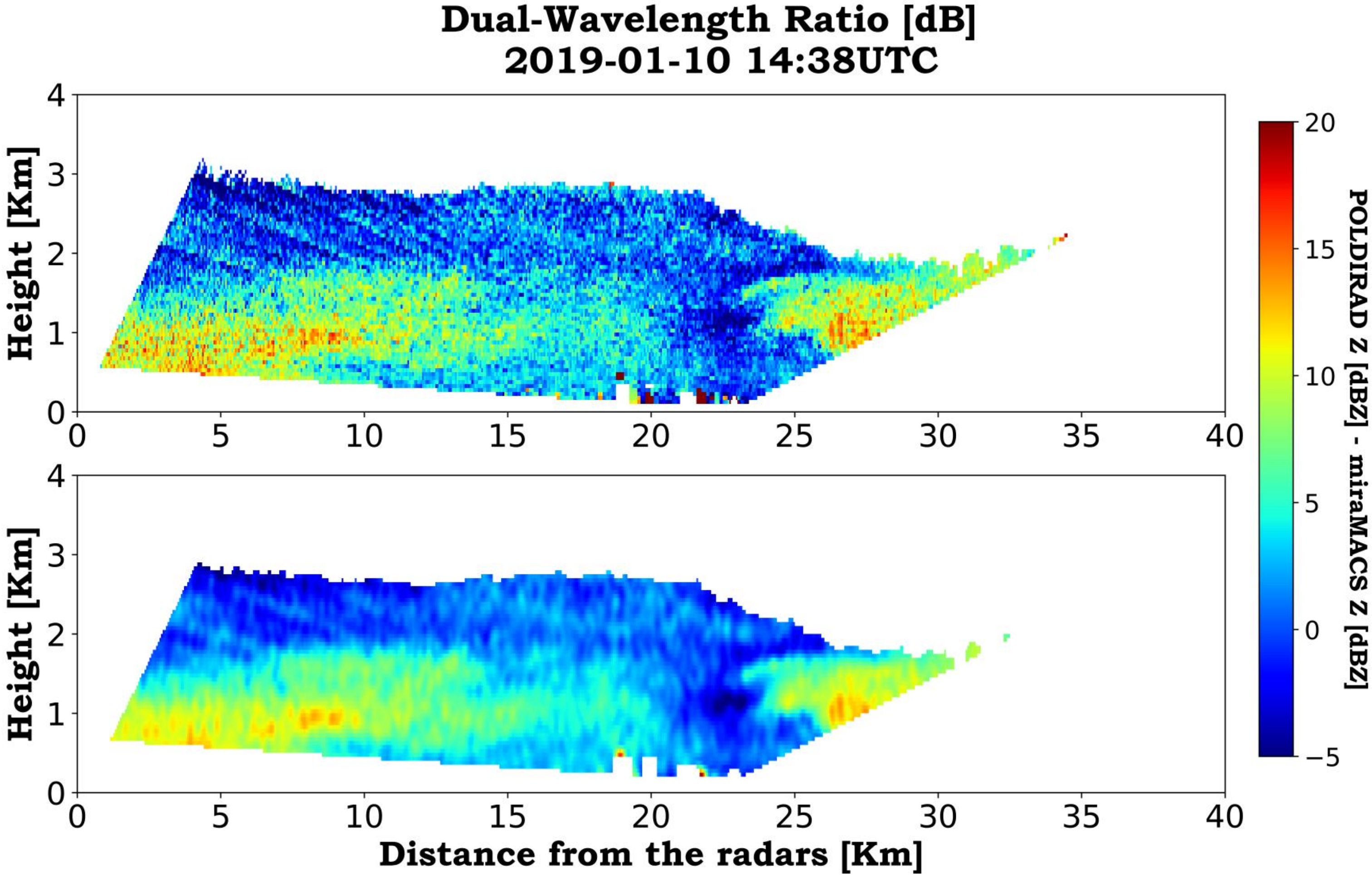
# Measurements:

## Example from 2019.01.10 14:38 UTC - On axis RHI scans

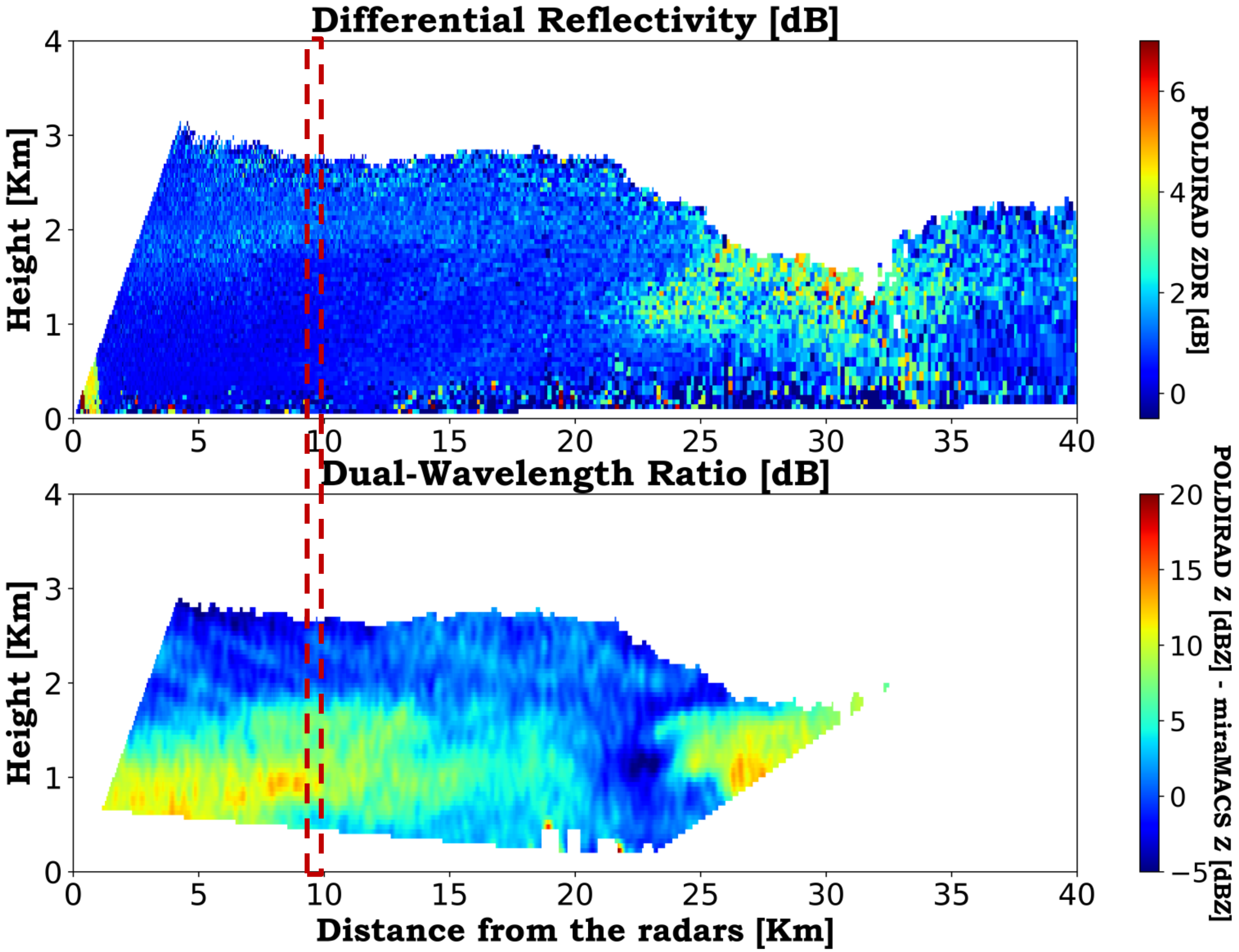



Applying a Gaussian filter to reduce some noise from the data.

# Methodology:

## Defining the dataset from DWR measurements

**Studying profile at 9.5 Km**

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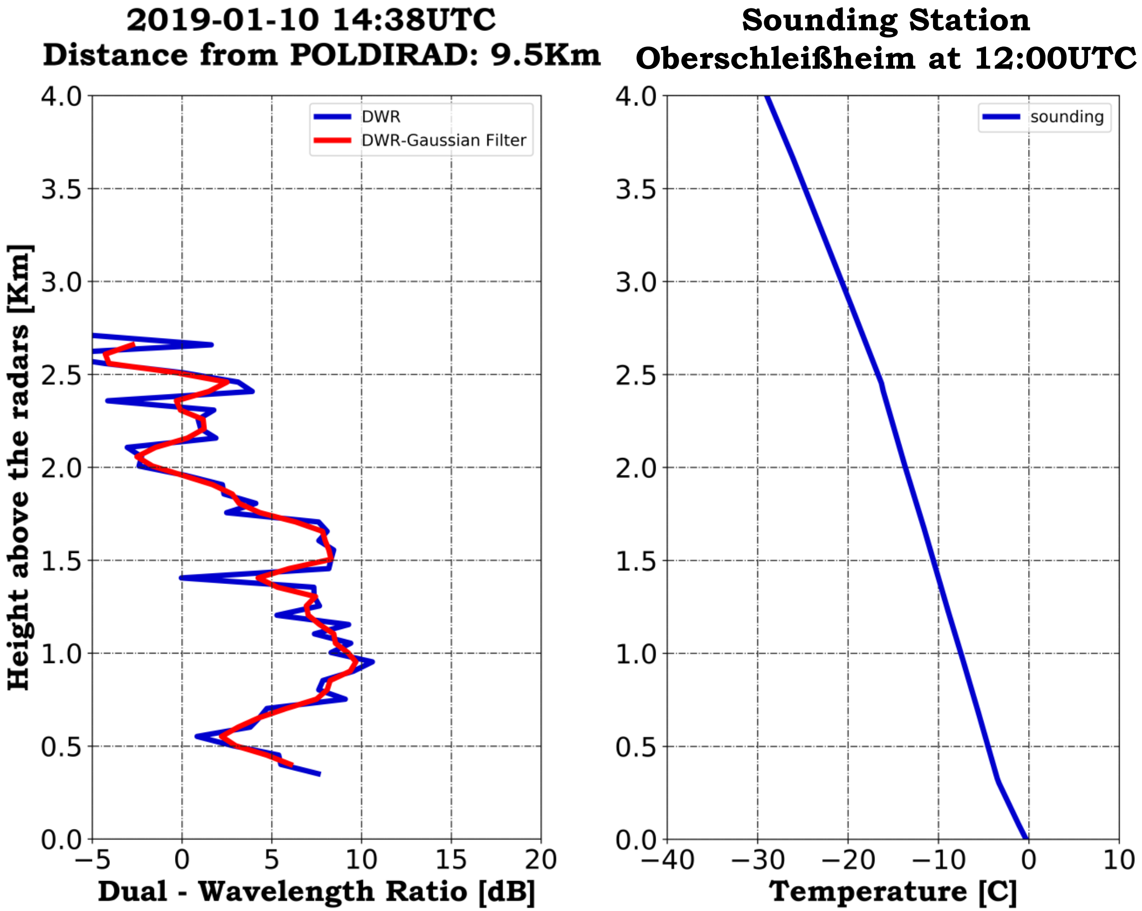
# Measurements and auxiliary data:
## Defining the dataset from DWR measurements




After the application of the Gaussian filter, all DWR values from each profile were used for further calculations.

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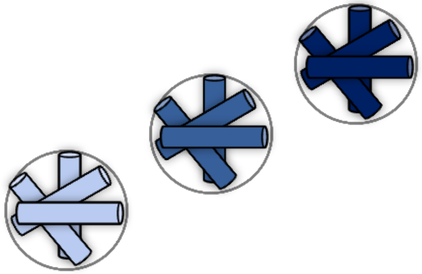
# Methodology
## Tmatrix Simulations for ice particles

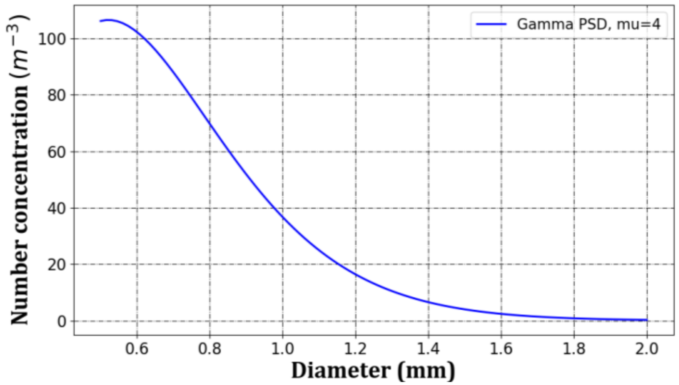
PyTmatrix

*Leinonen 2014*

Spheroid particles 

Ice particles with densities 0.1, 0.5, 0.9 g/cm$^3$

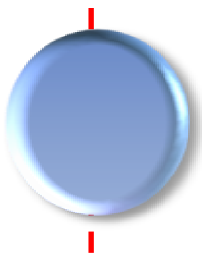


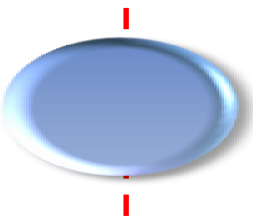



Particles that follow Gamma Distribution
with a width parameter 4

Particles with aspect ratio 0.6, 1.0, 1.4
(= The Horizontal to Rotational axis)

Prolate 

Spherical 

Oblate 

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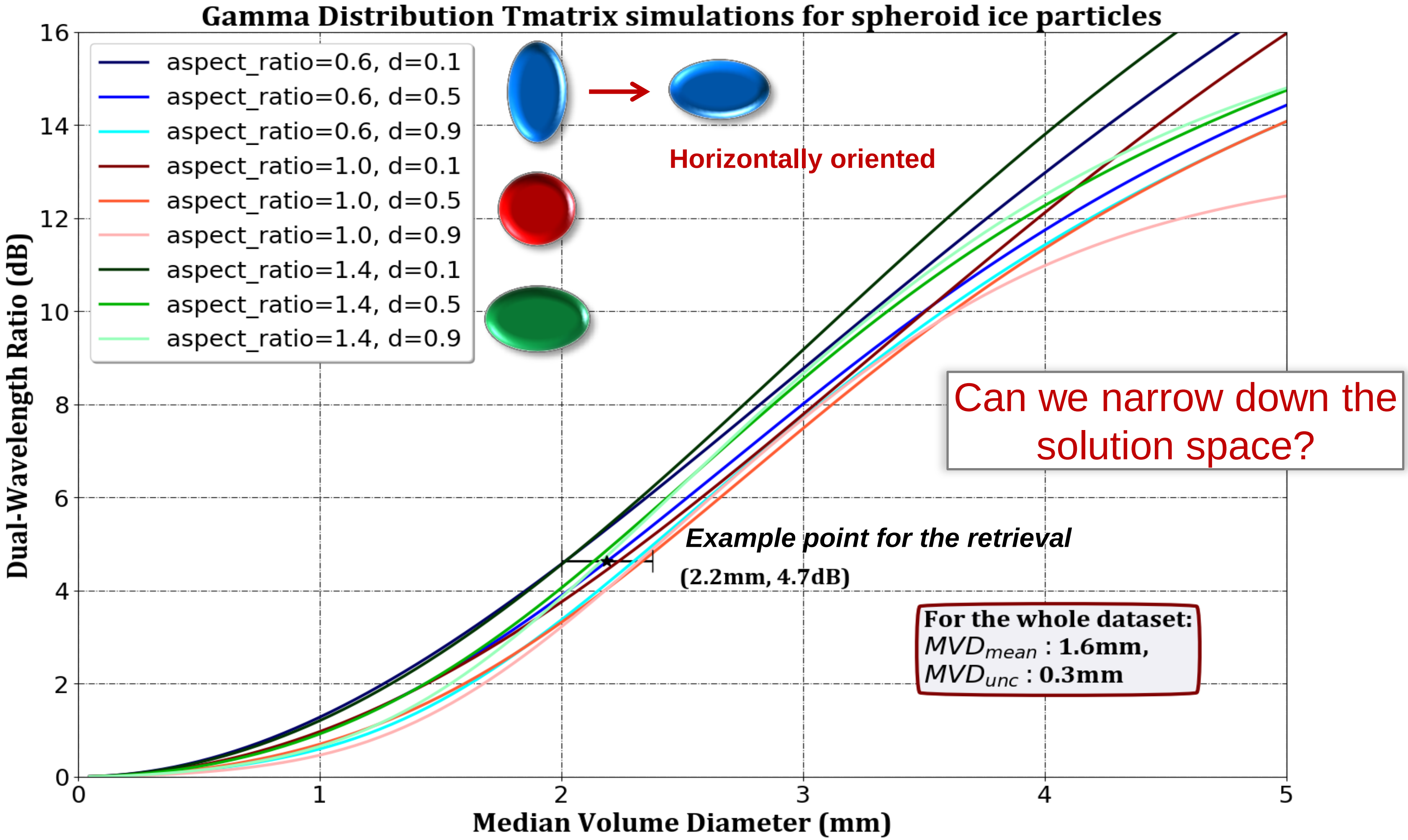
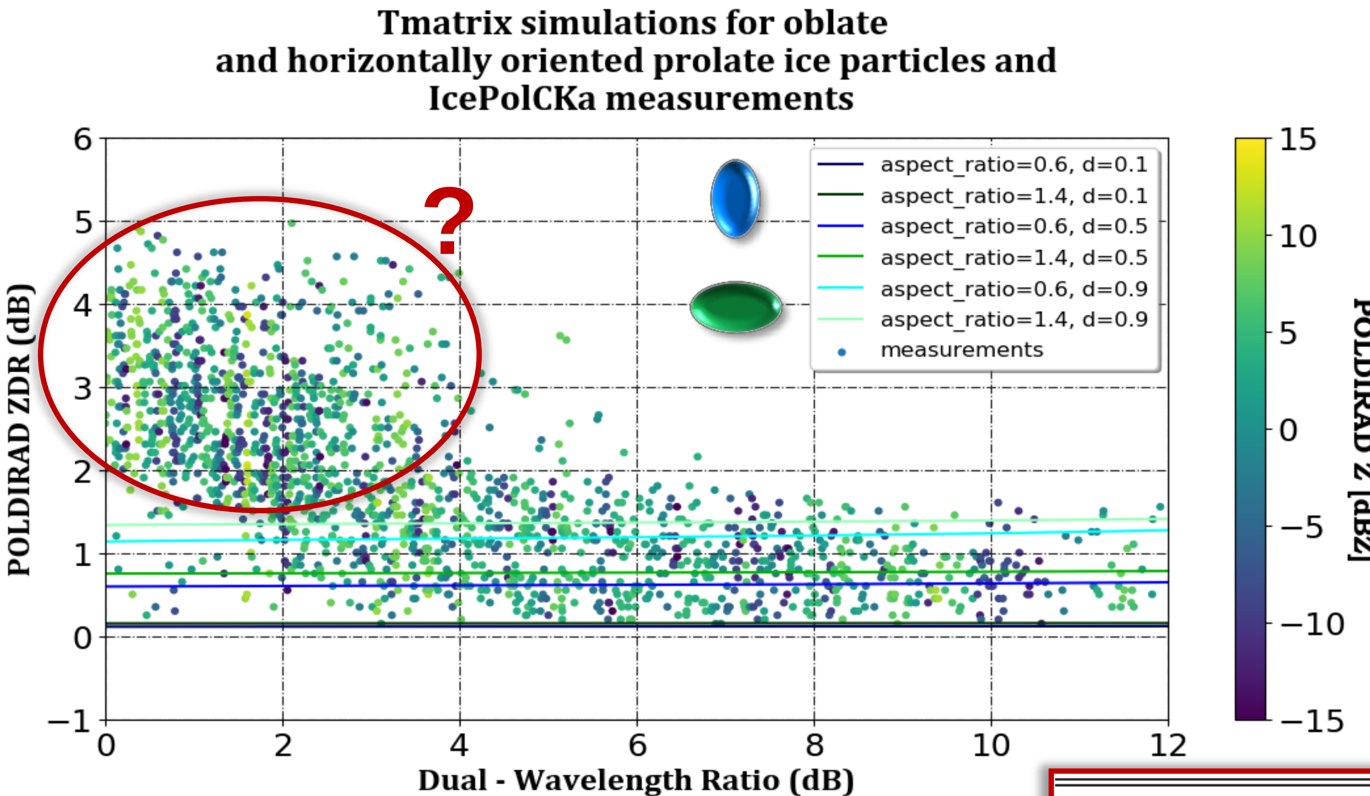
# Methodology

## MVD estimation from Tmatrix simulations and DWR measurements



# Methodology

## Which is the contribution of Polarimetry in this study?




Tmatrix simulations for spheroid ice crystals fit better to measurements with DWR > 4 dB

For DWR < 4 dB more aspherical ice particles dominate our dataset.

*Straka et al. 1999*

| Snow–crystals | | | $Z_h$ (dBZ) | $Z_{dr}$ (dB) |
|---|---|---|---|---|
| Snow–crystals | | | <45 | −0.5 to 6 |
| Snow aggregate | Dry | | <35 | 0–1 |
| | Wet | | <45 | 0.5–3 |
| Crystals (dry) | Vertical | | <35 | −0.5 to 0.5 |
| | Horizontal | | <35 | 0–6 |
| | Habit | Plate–dendrite | <35 | 2–6 |
| | | Column–thick plate | <35 | 1–4 |
| | | Needle–sheath | <35 | 0–3 |

Need for scattering simulations of other shapes hexagonal plates, columns, needles etc.

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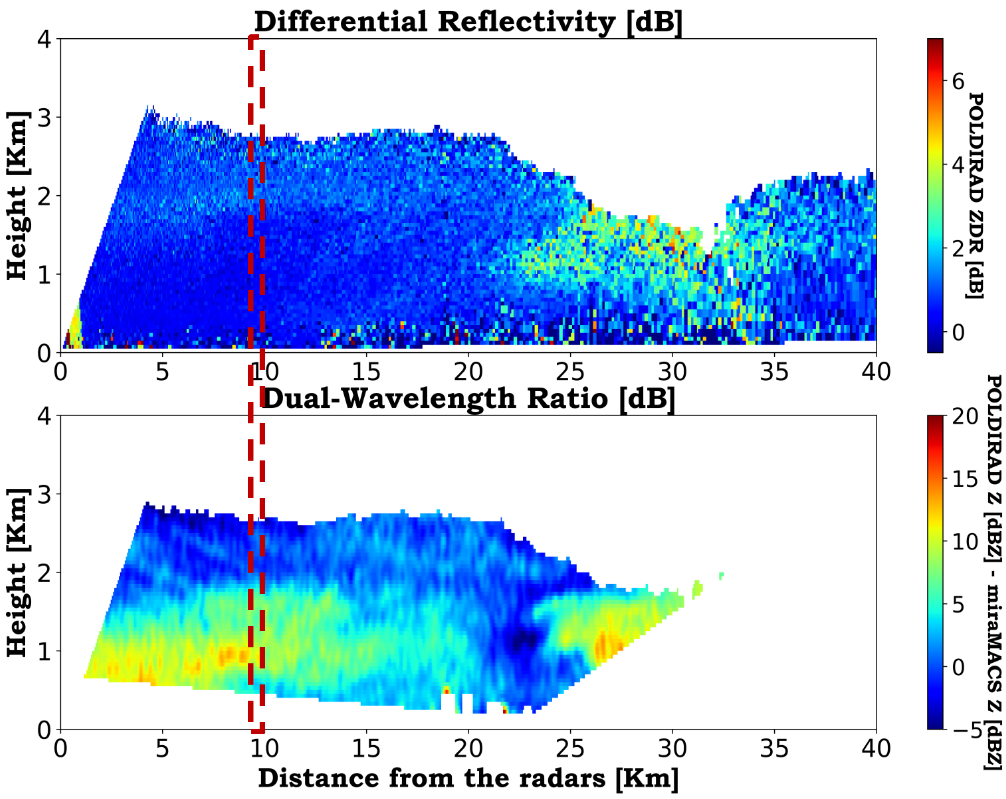
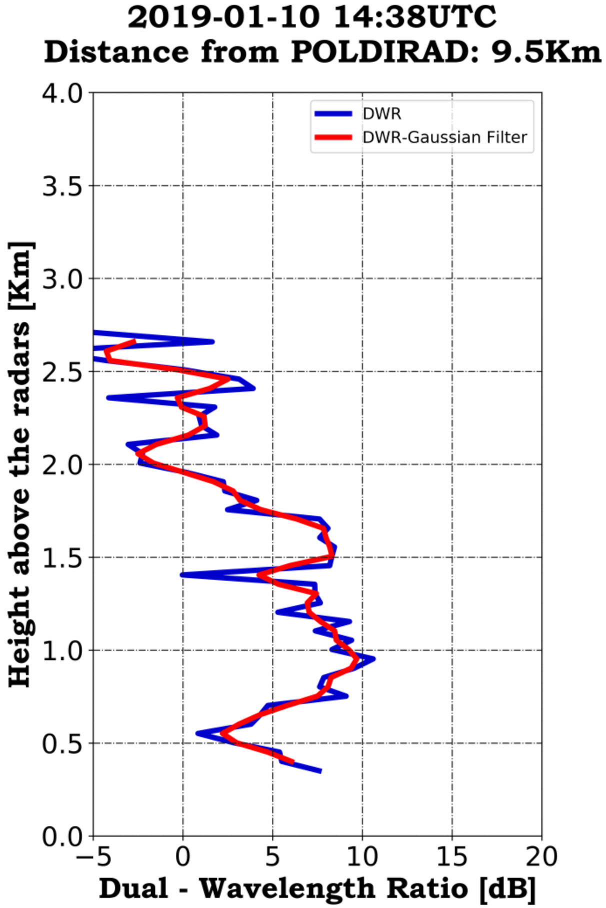
# Example for the approach

## Profile example from 2019.01.10 14:38 UTC




**Studying profile at 9.5 Km**

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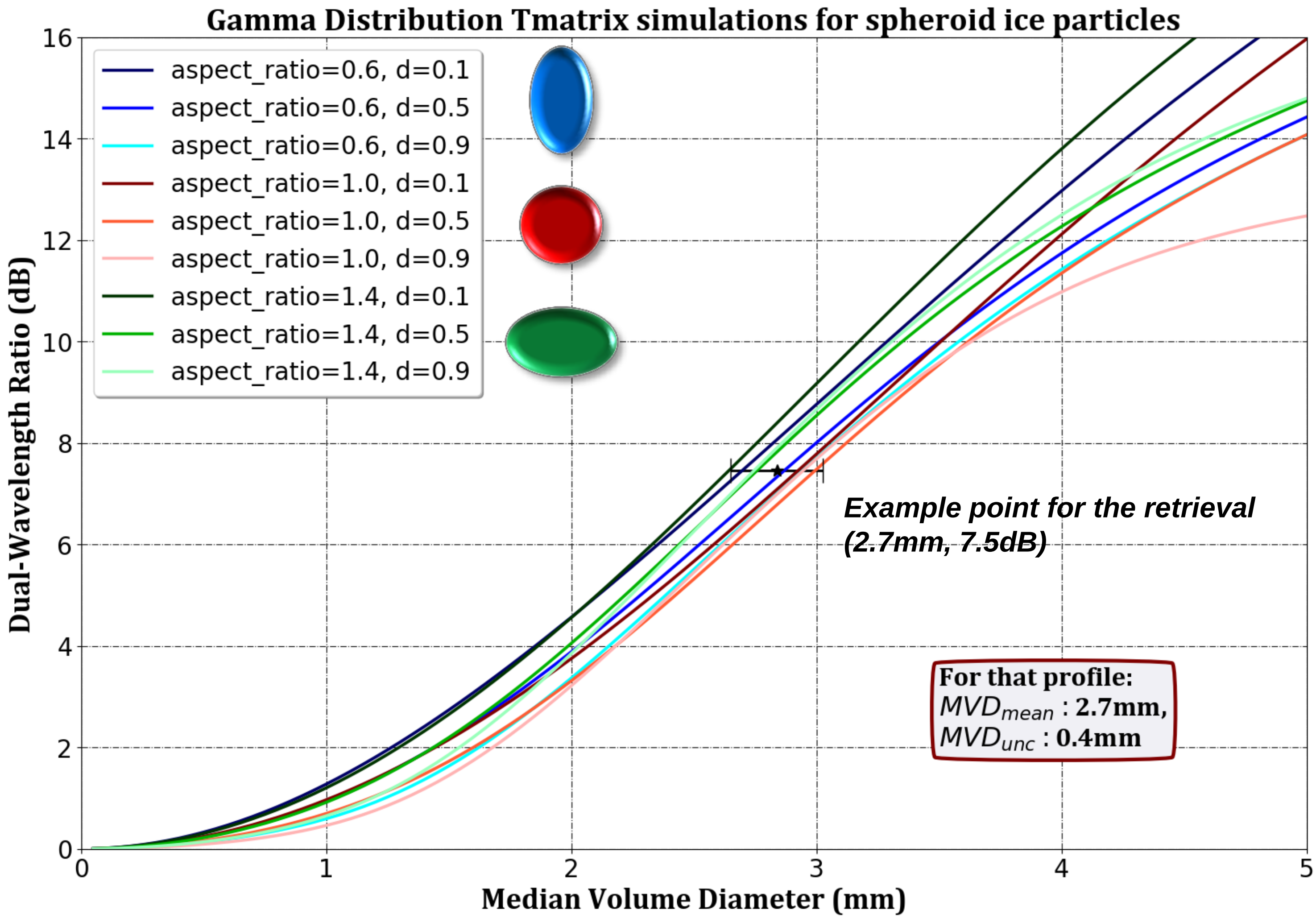
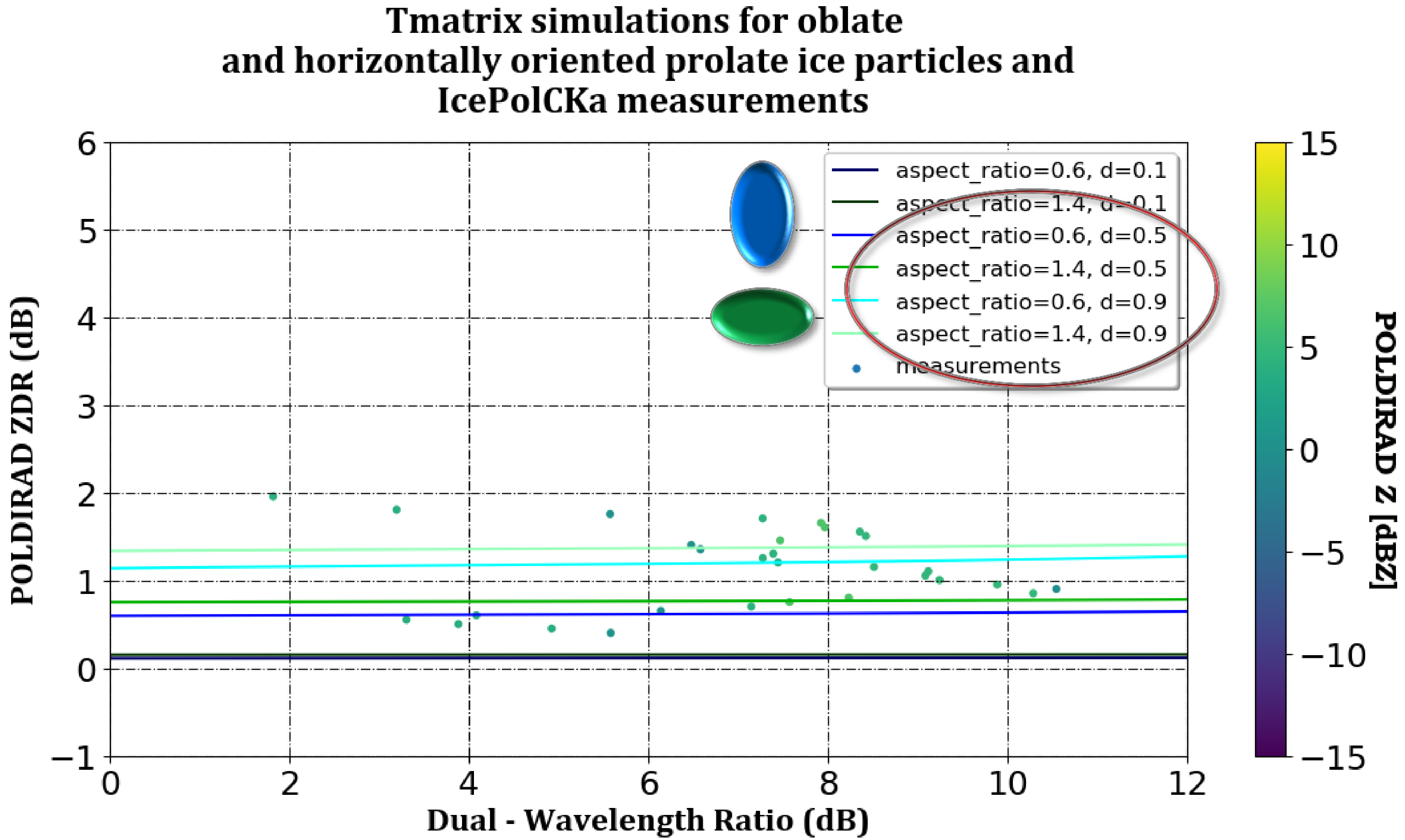
# MVD estimation from Tmatrix simulations and DWR

## Profile example from 2019.01.10 14:38 UTC

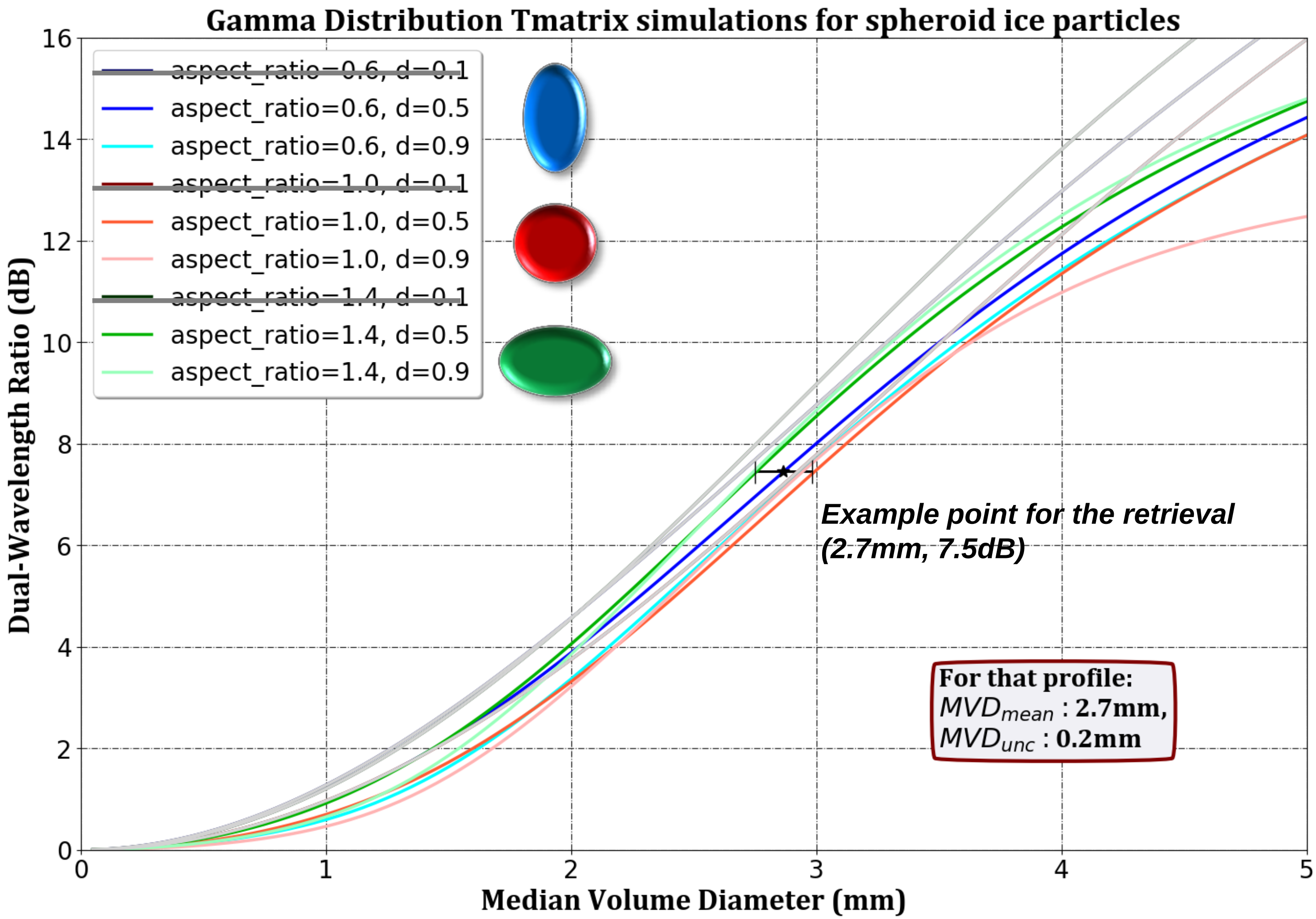


# Tmatrix simulations, DWR and Polarimetry measurements
## Profile example from 2019.01.10 14:38 UTC



# MVD estimation with the contribution of Polarimetry

## Profile example from 2019.01.10 14:38 UTC

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# Conclusions

From the Tmatrix simulations for spheroid ice particles and measurements was found a mean

MVD: 1.6 ± 0.3mm, for the whole dataset

MVD: 2.7 ± 0.4mm, for the profile on 2019.01.10 14:38 UTC

MVD: 2.7 ± 0.2mm, for that profile with the contribution of polarimetry and particles with density between 0.5 – 0.9 $gcm^{-3}$ (in dependence to the parametrizations used)

when no mass-size relation was used in the simulations.

# Current studies

## Tmatrix Simulations for ice particles using m(D) relations

PyTmatrix

*Leinonen 2014*

Spheroid particles 

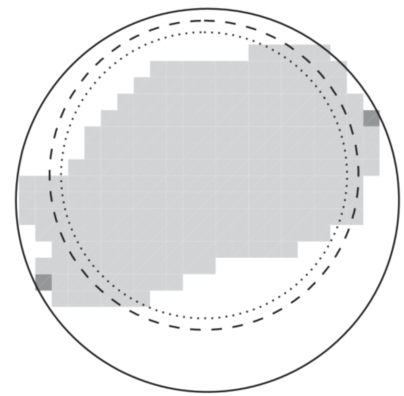
Particles that follow Gamma Distribution with a width parameter 4

Particles with aspect ratio 0.6, 1.0, 1.4

Mass – Size relation: Modified Brown and Francis (1995)

$$m = 480 D_{max}^{3}; \quad D_{max} < 6.6 \times 10^{-5}\,\mathrm{m},$$
$$m = 0.0121 D_{max}^{1.9}; \quad D_{max} \geq 6.6 \times 10^{-5}\,\mathrm{m}$$

*Hogan et al. 2012*



—— $D_{max}$ (584 μm)
- - - $D_{mean}$ (475 μm)
······ $D_{area}$ (436 μm)

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# Future studies

- *Use of different m-D relations in Tmatrix*
- *Use of different shapes for ice crystals simulations*
- *Use of different scattering algorithms and intercomparisons*
- *Use of more polarimetric variables for the development of a classification algorithm*
- *Effects of attenuation and cloud inhomogeneities on DWR*
- *EUREC4A research campaign 2020 in Barbados.*