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

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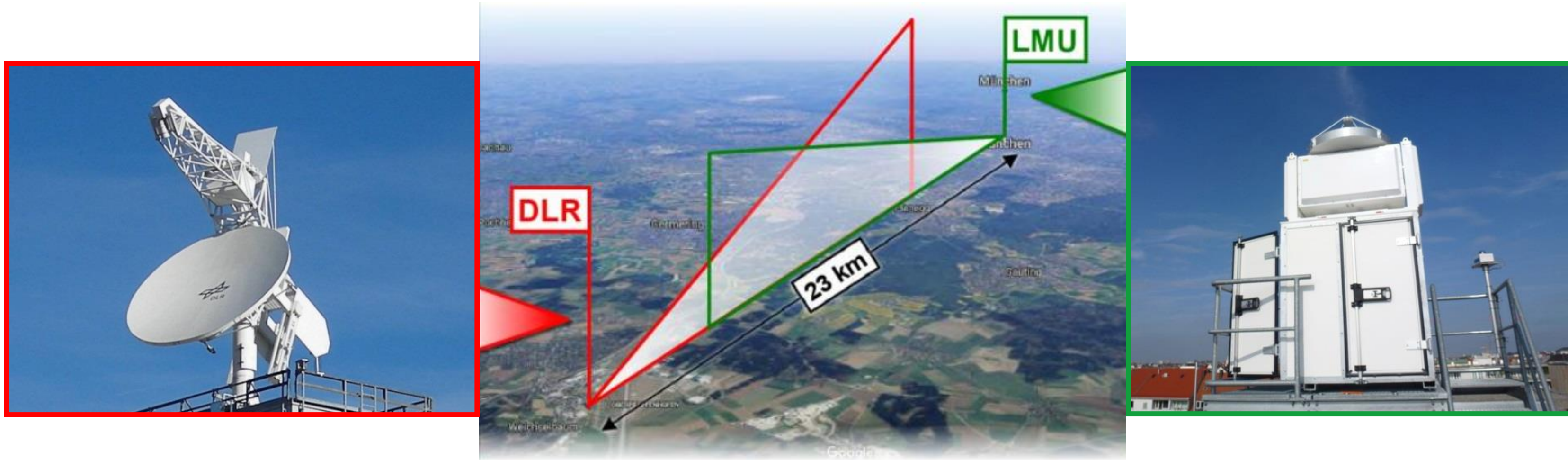
IcePolCKa:



- ✓ Synergy of two full polarimetric radars, POLDIRAD at DLR, Oberpfaffenhofen and MIRA-35 at LMU, Munich.
- ✓ Monitoring stratiform precipitation (cross-section area, on-axis setup).
- ✓ Tracking convective cells (cross-section profile, off-axis setup).

***IcePolCKa**: Investigation of the initiation of convection and the evolution of precipitation using simulations and polarimetric radar observations at C- and Ka-band*

Developing an ice microphysics retrieval scheme

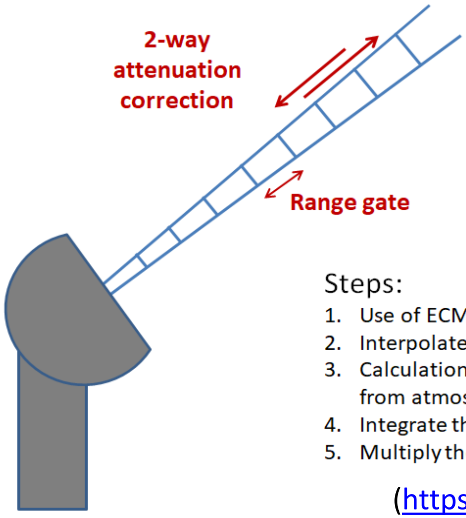
Main research goal:
Use of Dual-Wavelength and polarimetric radar observations to study the role of ice in the initiation of precipitation.

1. **Preprocessing/Correction**
   - **a.** Correction for gaseous attenuation
   - **b.** Interpolation of measurements on a common grid and identification of combined measurements
   - **c.** Mask for the ice phase

2. **Microphysics Retrieval**
   - **a.** Scattering simulations
   - **b.** Interpolation of viewing geometries
   - **c.** Technique for least squares minimization/ Measurements and simulations combination
   - **d.** Correction for hydrometeor attenuation

Preprocessing/Correction for gaseous attenuation:

Calculation using ITU and ECMWF



Steps:

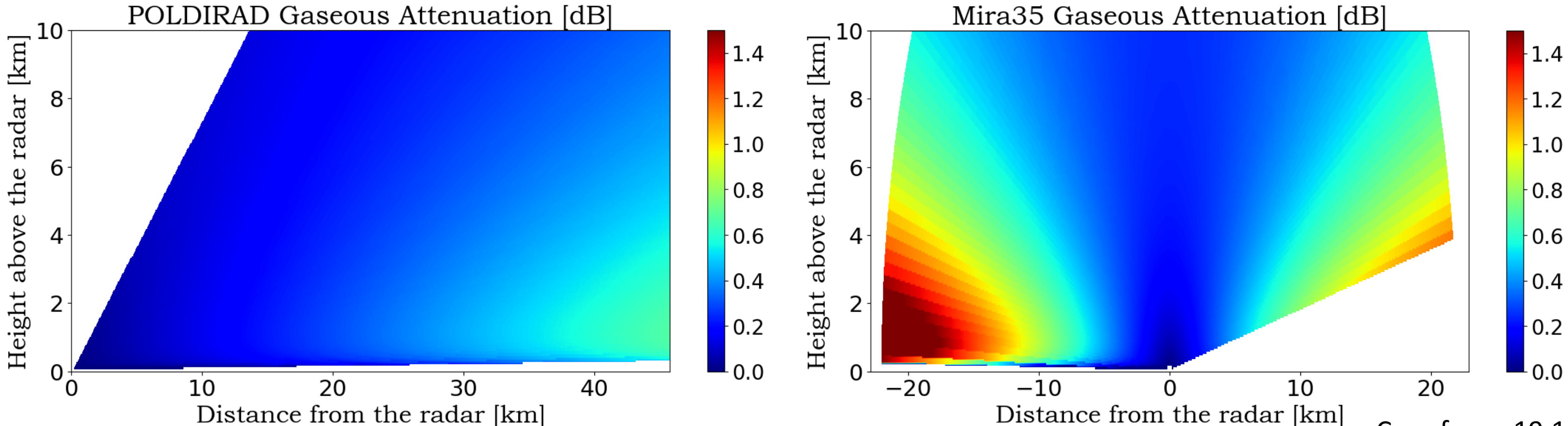
1. Use of ECMWF data (RH, T, P) and ITU model
2. Interpolate into the radar grid
3. Calculation of the total specific attenuation from atmospheric gases for each radar gate
4. Integrate through the radar beam
5. Multiply the result by 2

- International Telecommunications Union model

(ITU: Recommendation ITU-R P.676-11: Attenuation by atmospheric gases, International Telecommunications Union, 2016)

- ECMWF ERA5 hourly data

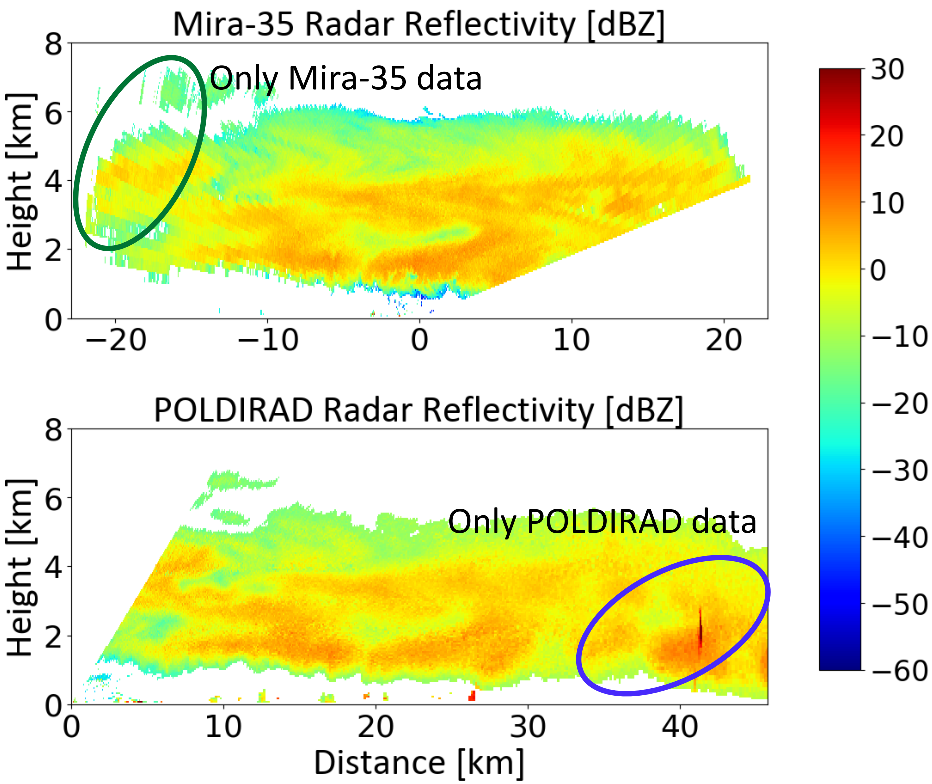
(https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-pressure-levels?tab=overview)

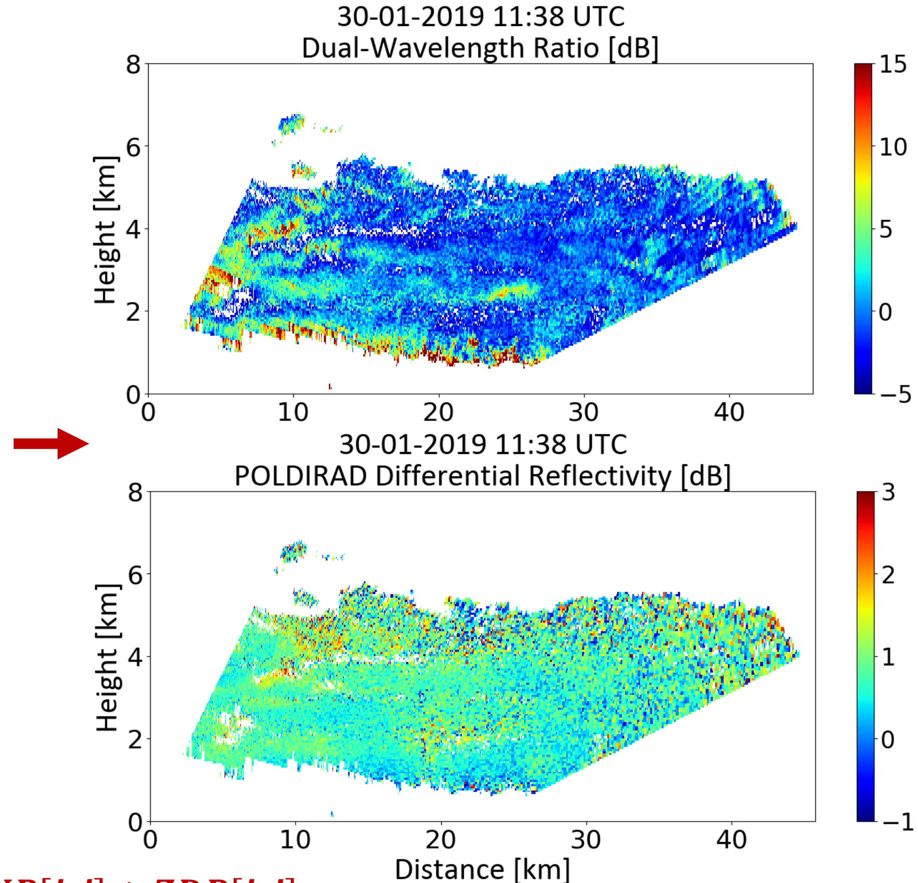


Case from: 19.11.2018

Preprocessing:
Interpolation on a rectangular grid/Defining the common cells

Example from 30.01.2019 at 11:38UTC

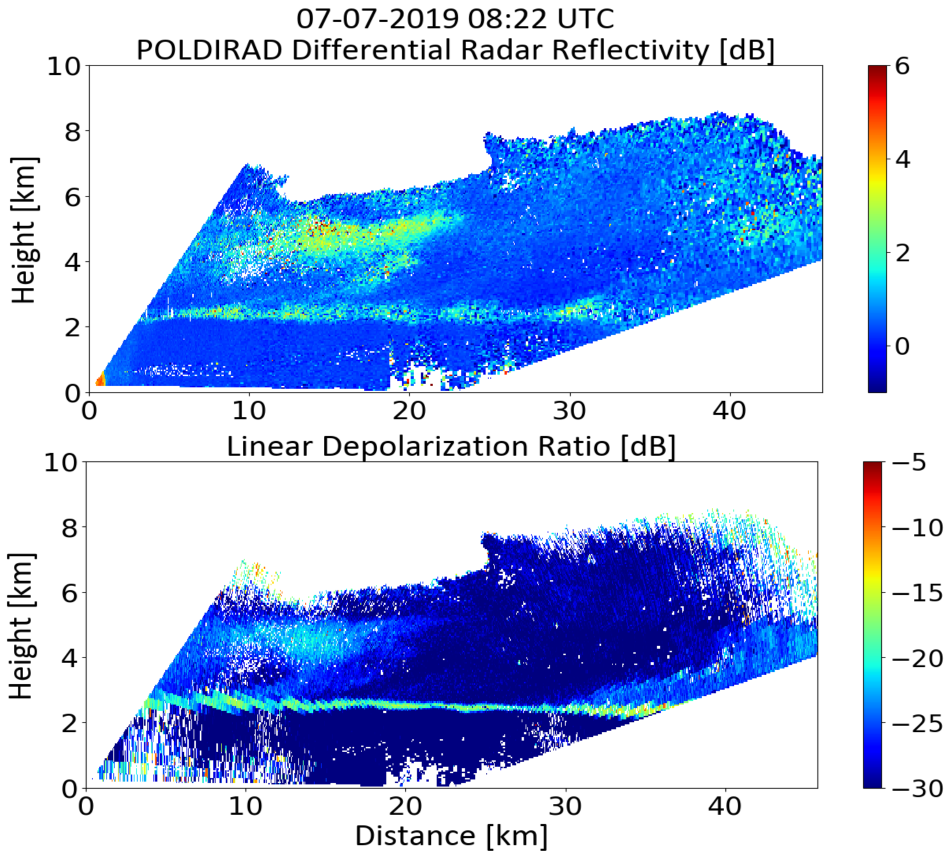




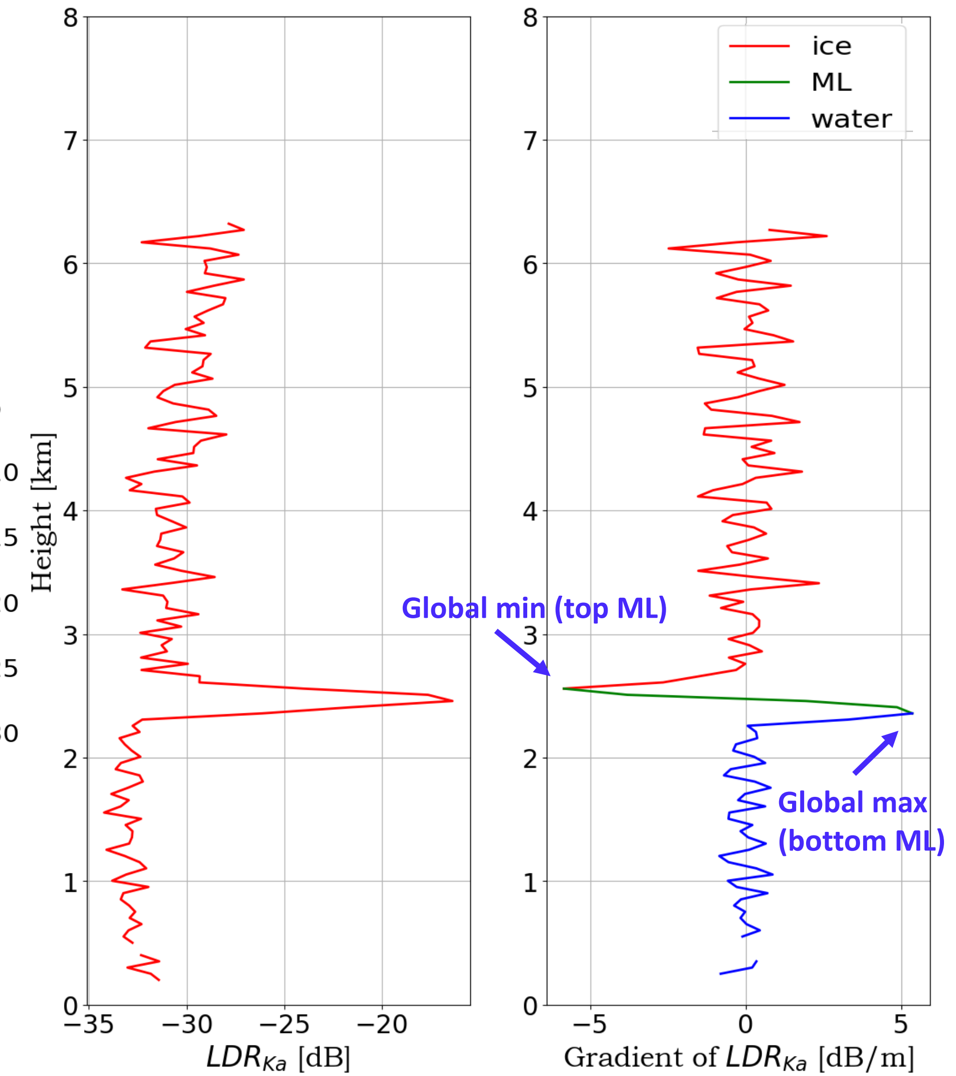
$$\boldsymbol{combined\ measurement[i,j] = Z_c[i,j] + DWR[i,j] + ZDR[i,j]}$$

*i = [0, 299], j = [0, 799]

Preprocessing:
Masking for the ice part of the cloud



Profile at ~23km from POLDIRAD



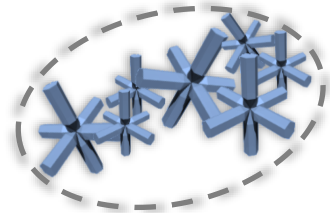
2 > ZDR_C > 1.5dB **and**
0.99 > ρHV_C > 0.9 **and**
-15 > LDR_{Ka} > -22dB

→

Calculate ∇·LDR
Find extrema

Melting Layer Detection

Ice microphysics retrieval scheme:
IcePolCKa Scattering Database (IcePolCKa SD)



Spheroid ice particles (oblates, spherical and horiz. aligned prolates).

Gamma particle size distribution.

Brown and Francis (1995) m-D relation (D_{max}, Hogan et al., 2012).

Developing Look-Up Tables (LUTs) to use in the ice microphysics scheme.

PyTmatrix

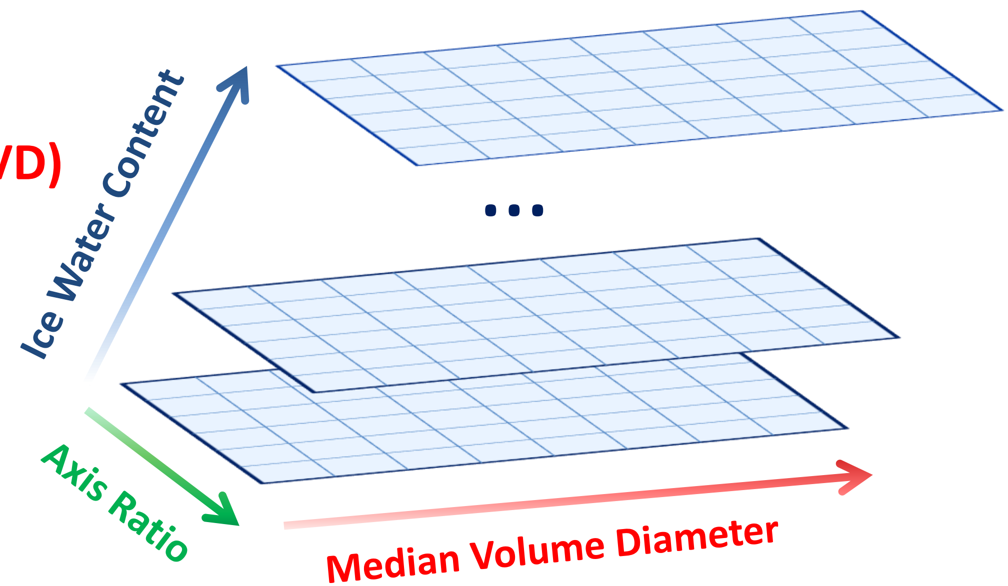
(Leinonen 2014)

Using 3 variables:

- ✓ **Ice Water Content (IWC)**
- ✓ **Median Volume Diameter (MVD)**
- ✓ **Axis Ratio**

Calculations for:

Z_c, Z_{Ka},
DWR,
ZDR
specific attenuation γ_C, γ_{Ka}



Current grid resolution: 24, 35, 21

Ice Microphysics retrieval scheme:
Minimization using normalization

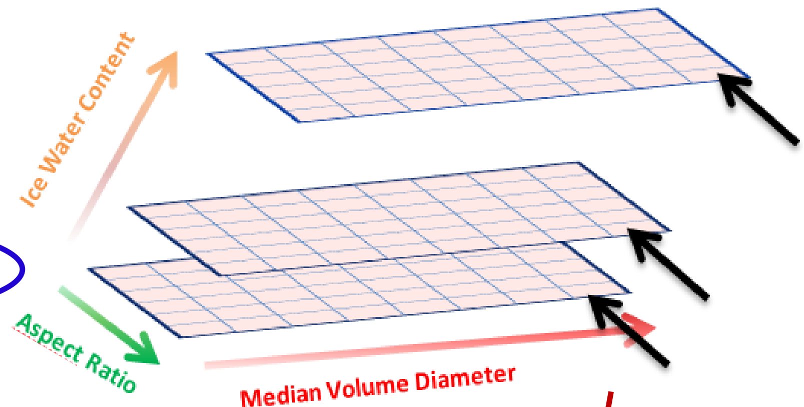
$$\min(J_1) = norm(\Delta ZDR) + norm(\Delta DWR)$$
$$\min(J_2) = norm(\Delta Z_c)$$

Δ: absolute difference between combined measurement component and simulations

The algorithm:

1. As DWR and ZDR don't change with IWC, it directly uses a dwr and zdr from a combined measurement to retrieve Aspect Ratio and MVD minimizing the cost function J_1.

$$\boldsymbol{combined\ measurement}[i,j] = Z_c[i,j] + DWR[i,j] + ZDR[i,j]$$



2. Retrieves IWC using normalised min difference of poldirad reflectivity to the simulated, minimizing cost function J_2.

Assuming lower right cell minimizes J_1, three solutions for IWC are possible

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Preprocessing/Correction for hydrometeor attenuation:
Forward technique for hydrometeor attenuation estimation

Hydrometeor attenuation correction

→ significant for a robust microphysics retrieval.

Methodology to calculate hydrometeor attenuation using the ice microphysics retrieval scheme – 2 step retrieval:

First retrieval of IWC, AR, MVD → **using minimalization indices** → Specific attenuation γ_C, γ_{Ka} estimation → convert to polar grid → Total attenuation a_C, a_{Ka} estimation

↓ convert to cartesian grid

Radar reflectivities Z_C, Z_{Ka} correction → Final retrieval of IWC, AR, MVD

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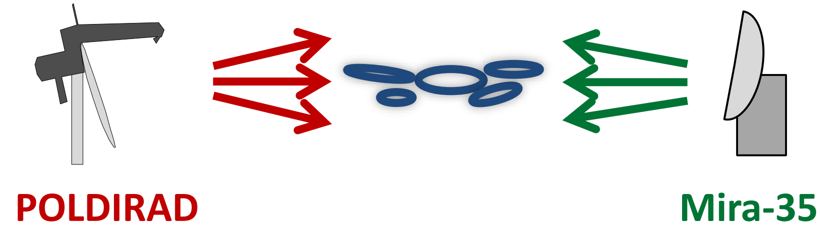
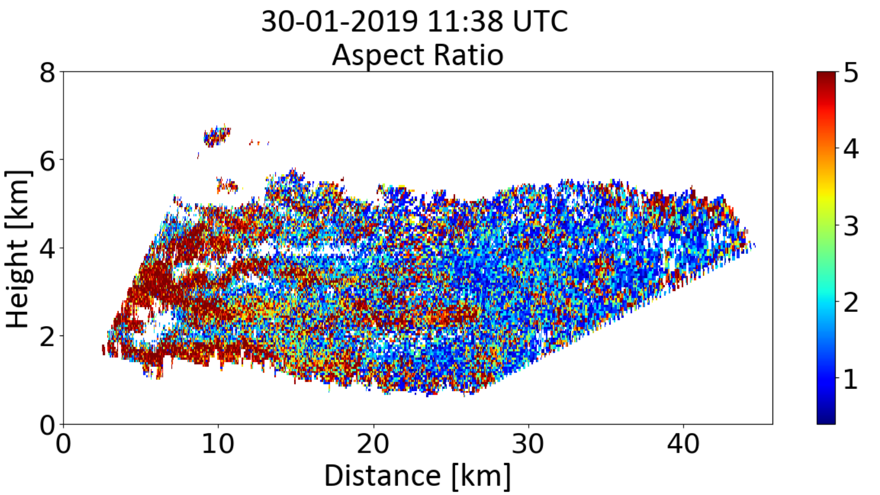
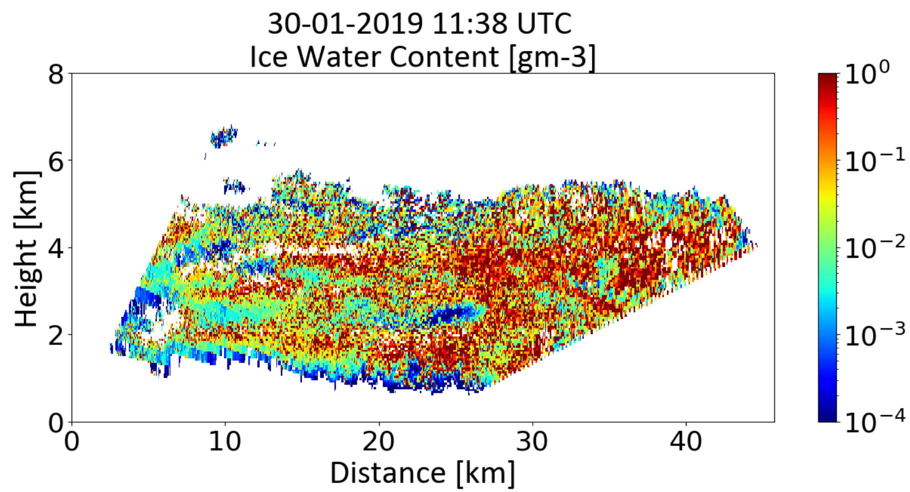
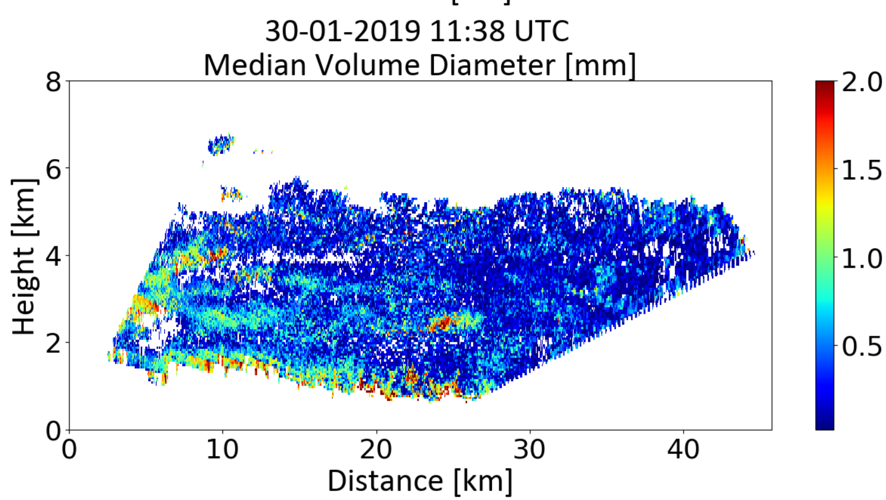
Ice Microphysics retrievals for multiple observation geometries

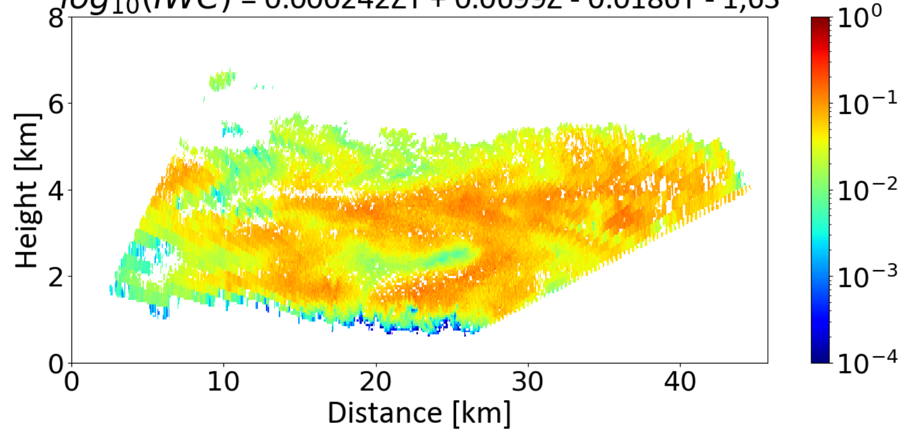








$log_{10}(IWC)$ = 0.000242ZT + 0.0699Z - 0.0186T - 1,63



Hogan et al., 2006

Temperature data: Oberschleißheim

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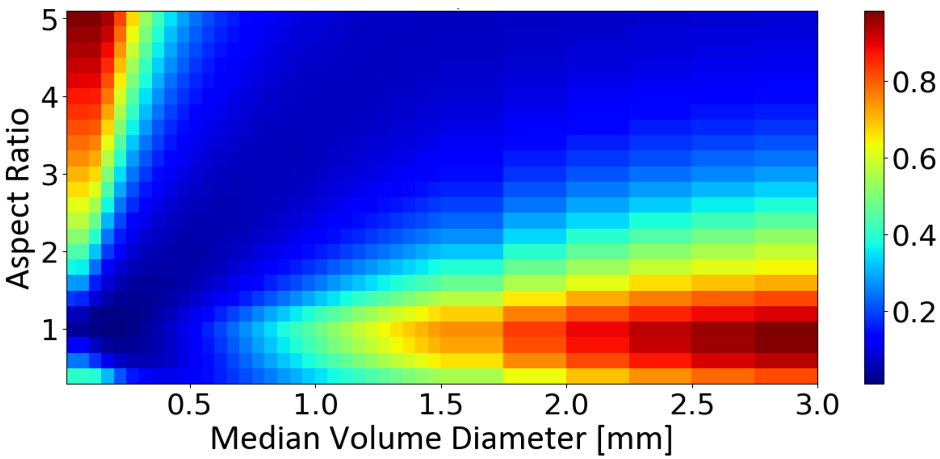
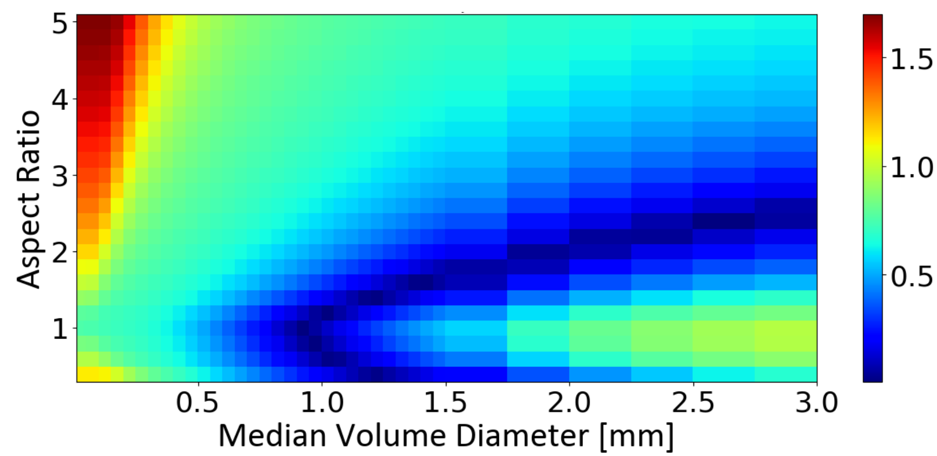
Ice Microphysics Retrieval scheme:
LUTs investigation

$$J_1 = norm(\Delta ZDR) + norm(\Delta DWR)$$

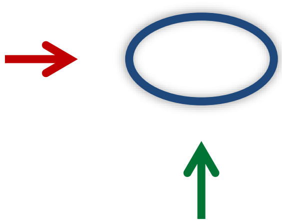
Normalised Differences for ZDR=0dB and DWR=0dB,



Normalised Differences for ZDR=0dB and DWR=12dB,



The algorithm currently wanders in two valleys (blue color) searching for the minimization of J_1.



Horizontal direction for the C-band beam
Vertical direction for the Ka-band beam

Possible problem:

Low simulated ZDR values?

Are measurements well represented by Brown and Francis m-D relation?

Idea:

Use another habit

(e.g. aggregates approximation, Yang et al. 2000a)

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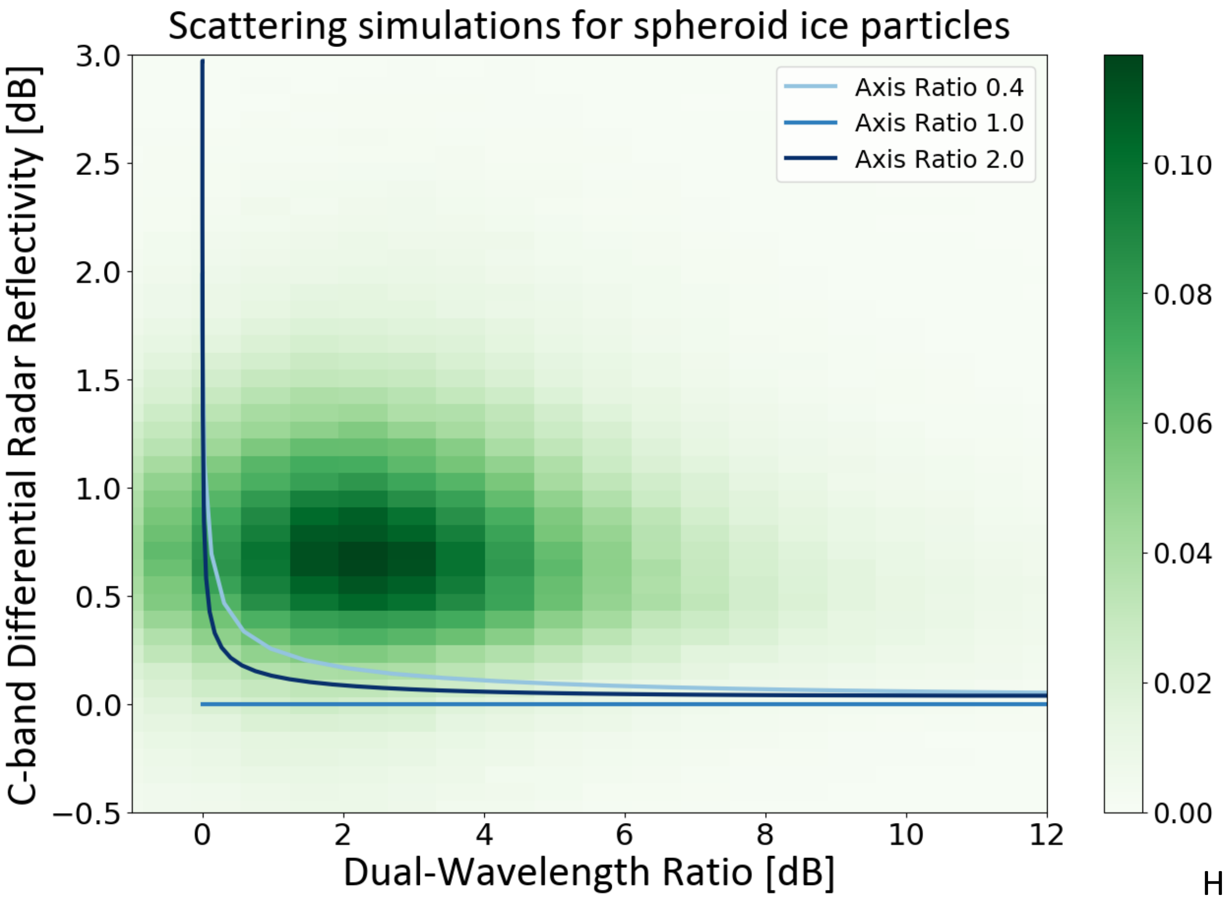
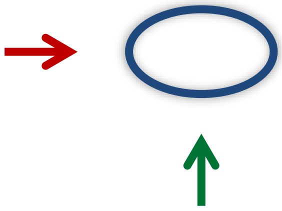
Ice Microphysics Retrieval scheme:
LUTs investigation



30.01.2019
16 pair of RHI scans



Horizontal direction for the C-band beam
Vertical direction for the Ka-band beam

Current studies and future work:

- To minimize algorithms instabilities:
  - Search for the most suitable particle model.
  - Test and finalize parts of the ice microphysics retrieval scheme (ice mask, hydrometeors attenuation estimation etc.).
- Compare PyTmatix simulations to another Scattering Database (e.g. ARTS Microwave Single Scattering Database)
- Examine more stratiform ice cases and do some statistical studies.
- *"Retrievals of ice microphysics using dual-wavelength radar polarimetric observations during stratiform precipitation events.", in a preparation stage…*

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