Investigation of Ice Microphysics using Simultaneous Measurements at C- and Ka-Band

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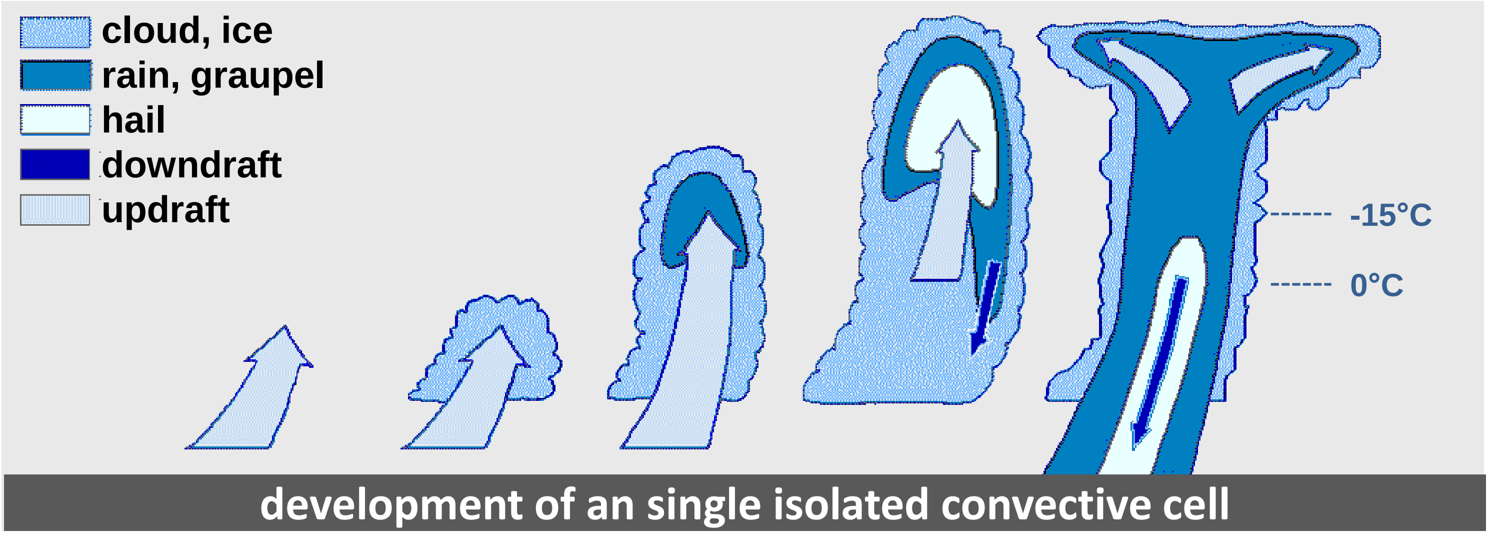
Understanding Precipitation Initiation in Mixed Phase Clouds

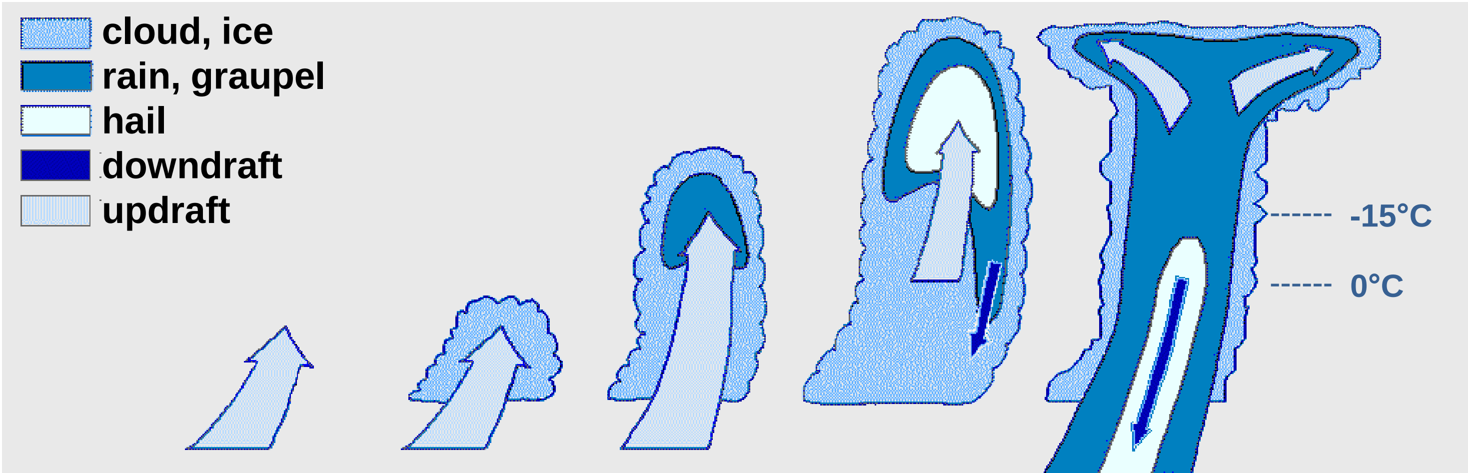


after Höller, 1994

Key Questions:

- when does precipitation initiation take place?
- when will ice be formed?
- how is precipitation initiation related to ice formation?

Understanding Precipitation Initiation in Mixed Phase Clouds



development of an single isolated convective cell

after Höller, 1994

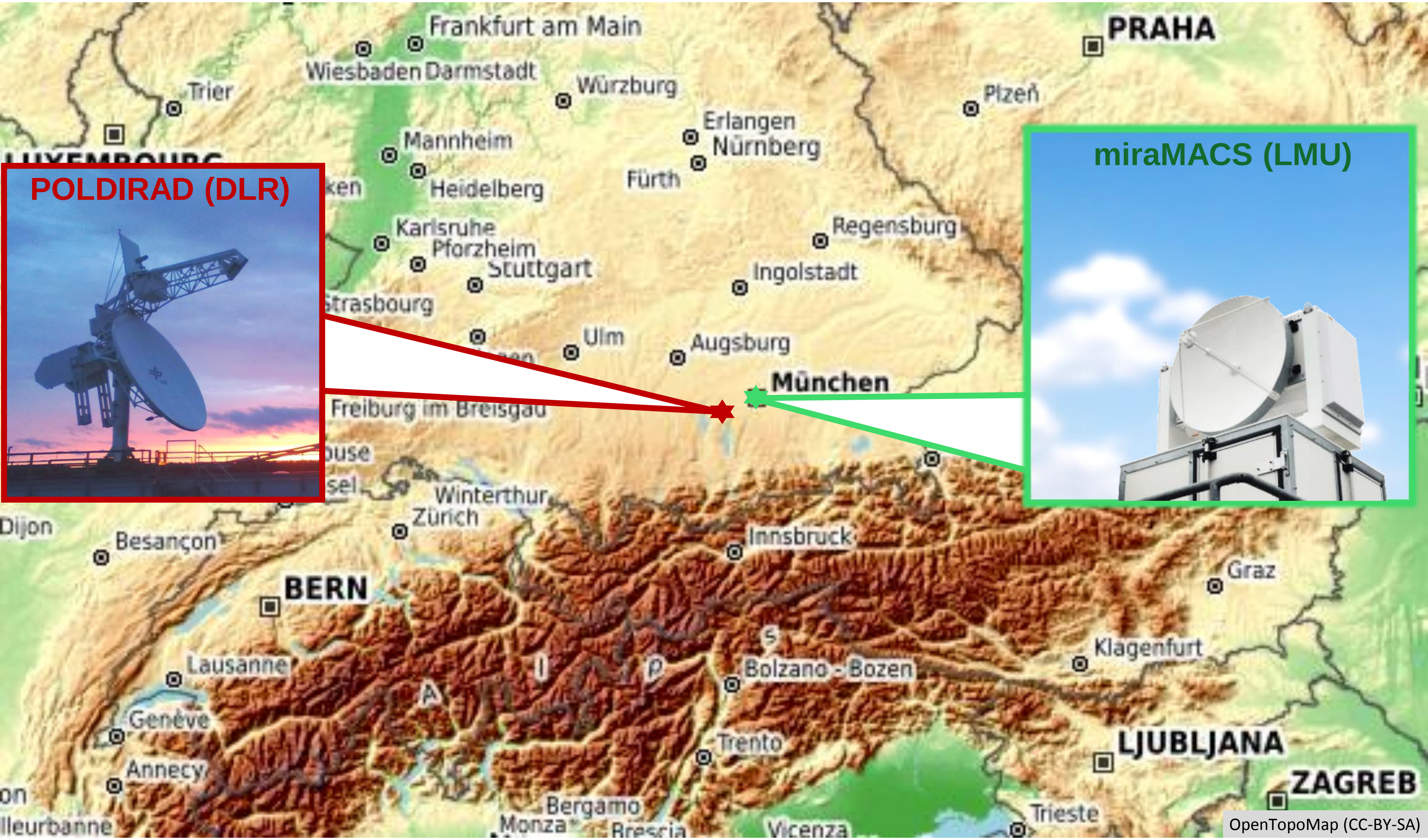
Radar point of view:

- dual-polarization hydrometeor classification
- reflectivity gives water / ice content
- ZDR, KDP, … tells about particle habit

Limitation:

- weather radar (X-, C-, S-) is not sensitive enough for small cloud particles
- cloud radar (Ka- or W-band) is affected by Mie resonance effects and suffers from attenuation
- both can derive only partly microphysical quantities or particle habits

Synergetic Measurements Poldirad – miraMACS



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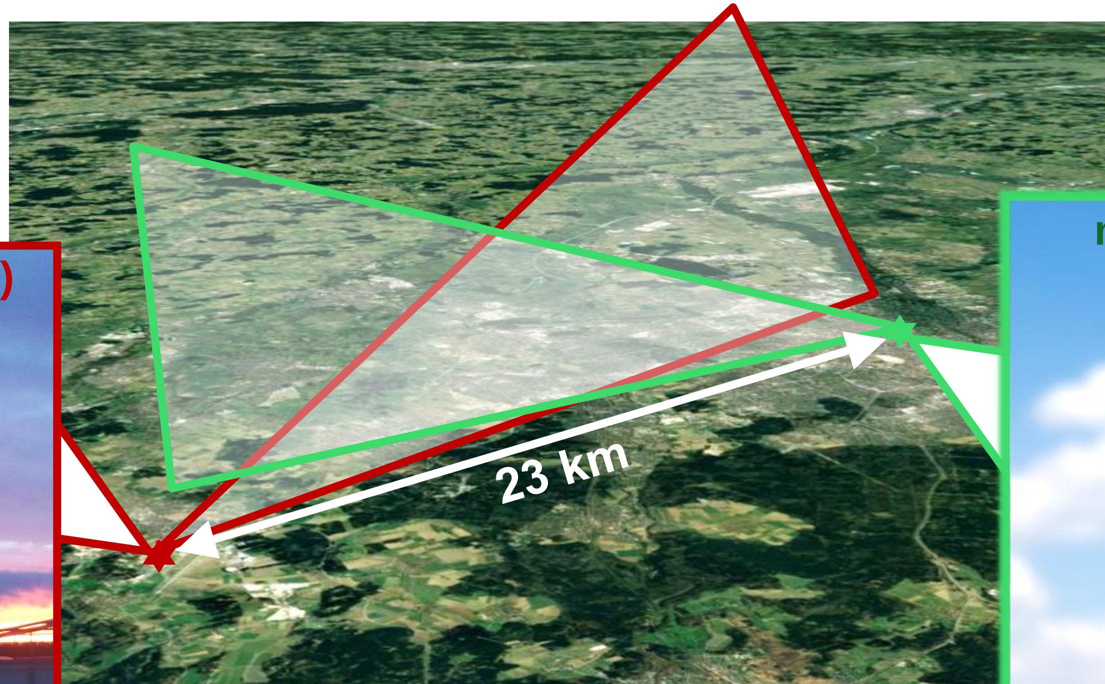
Coordinated RHI Measurements Poldirad – miraMACS

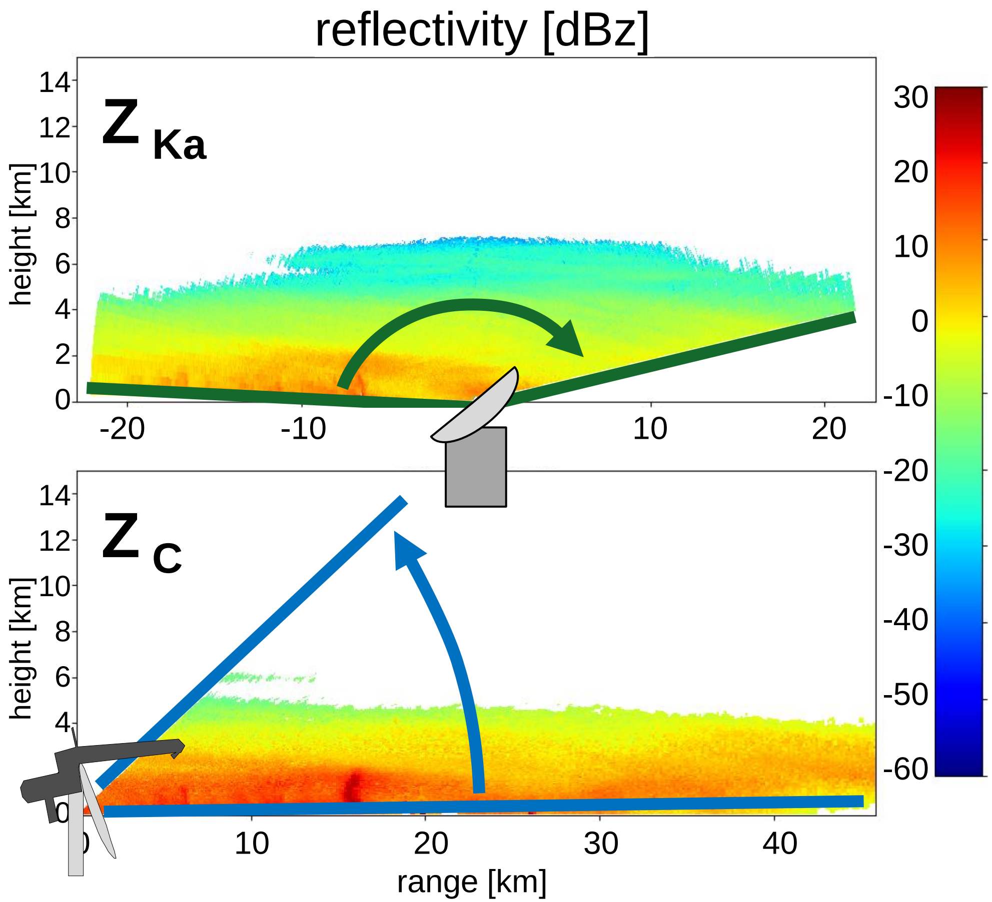


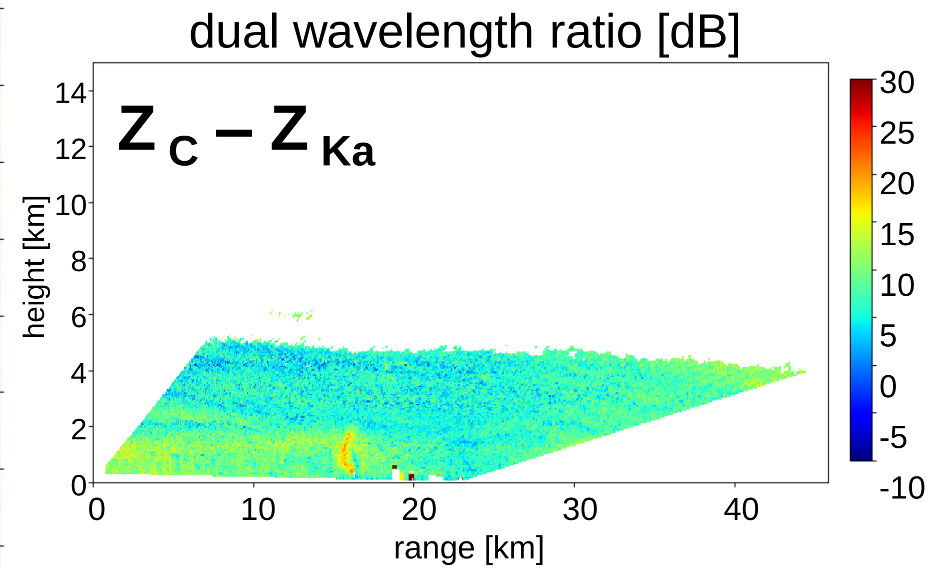
- C-band weather radar (5.5 GHz, 250 kW)
- operated at DLR Oberpfaffenhofen
- 4.5 m antenna 1° beam-width
- range res. 150 m, max 120 km
- full polarimetric (STAR and AltHV) (ZDR, LDR, KDP, rho_{HV})

- MIRA35 scanning Ka-band cloud radar (35.2 GHz, 30 kW)
- operated at LMU Munich city
- 1 m antenna 0.6° beam-width
- range res. 30 m, max 22 km
- linear depolarization ratio LDR

STAR: simultaneous transmit and receive
AltHV: alternate transmit and receive horizontal and vertical

Example Measurement 2019-01-09 12:09





23 km

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Example Measurement 2019-01-09 12:09

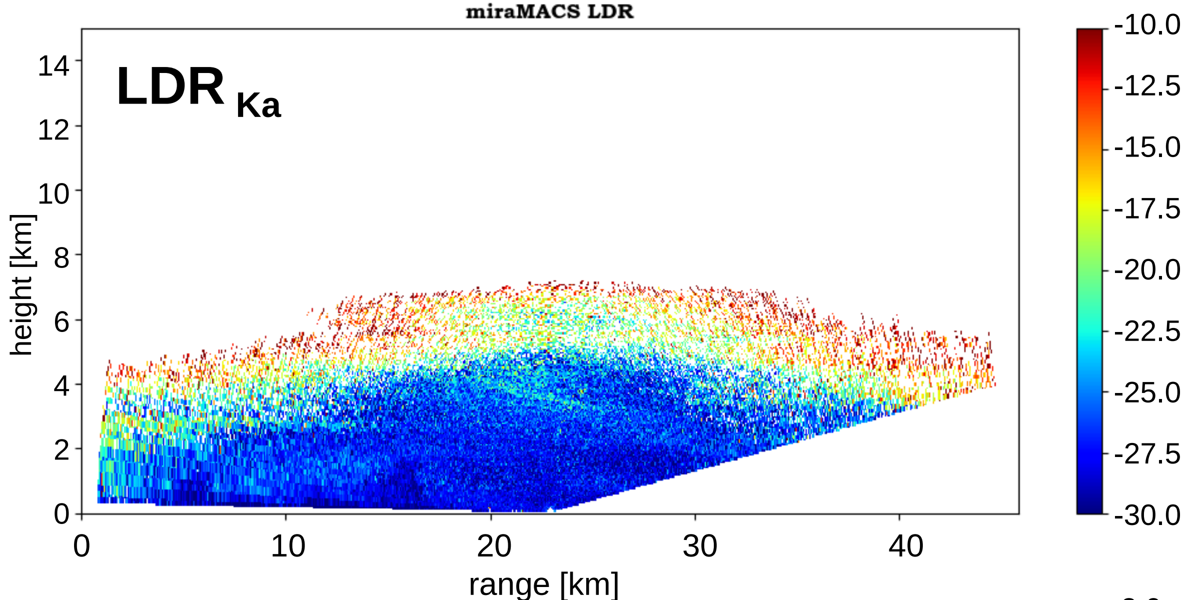
dual-polarization observations

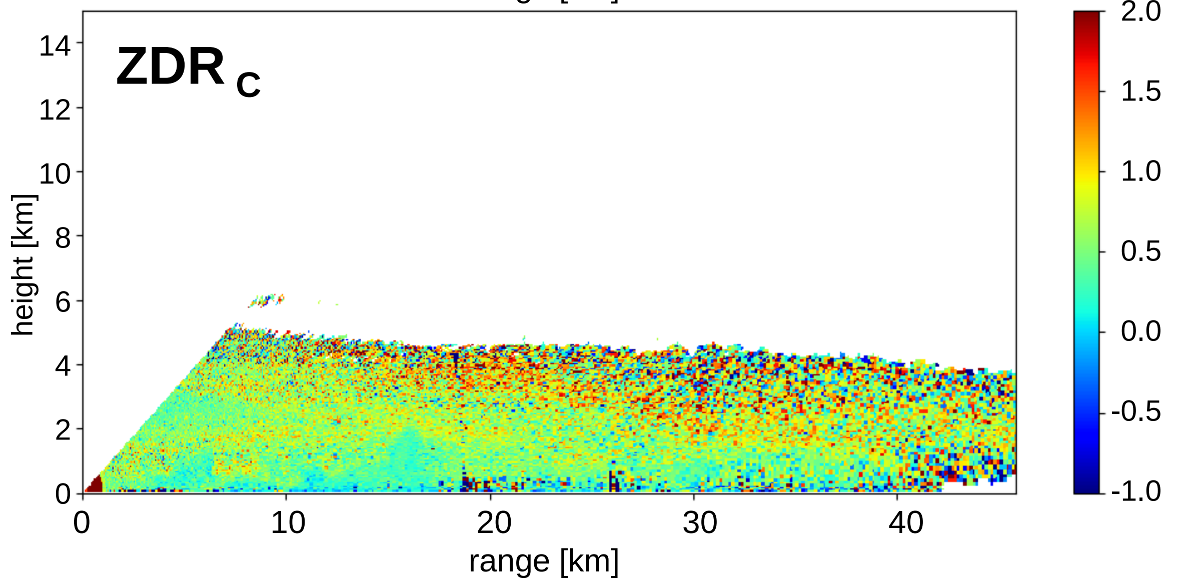
MIRA

- LDR: linear depolarization ratio: → irregular shapes

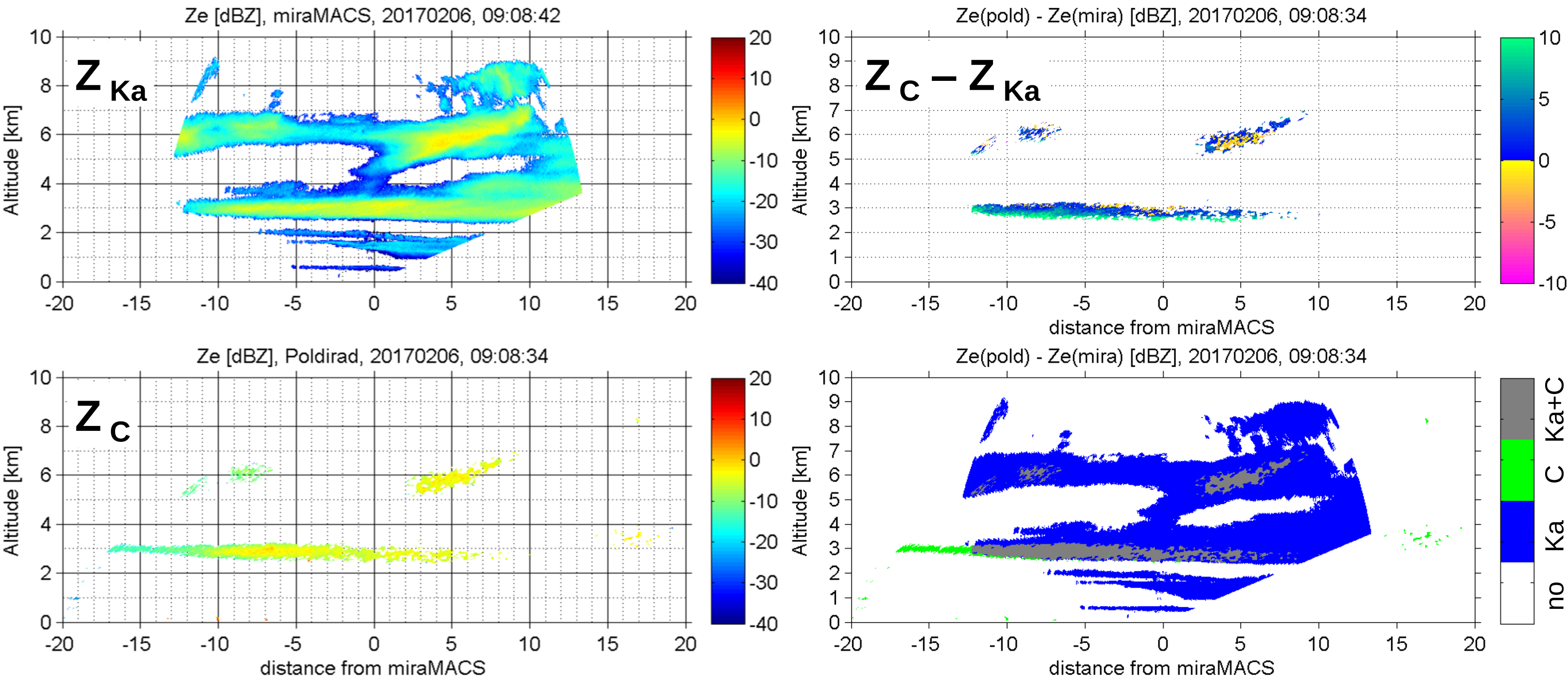
POLDIRAD

- ZDR: differential reflectivity: → elongated particles
- depolarization signal to weak to be seen





Example Measurement 2017-02-08 09:08

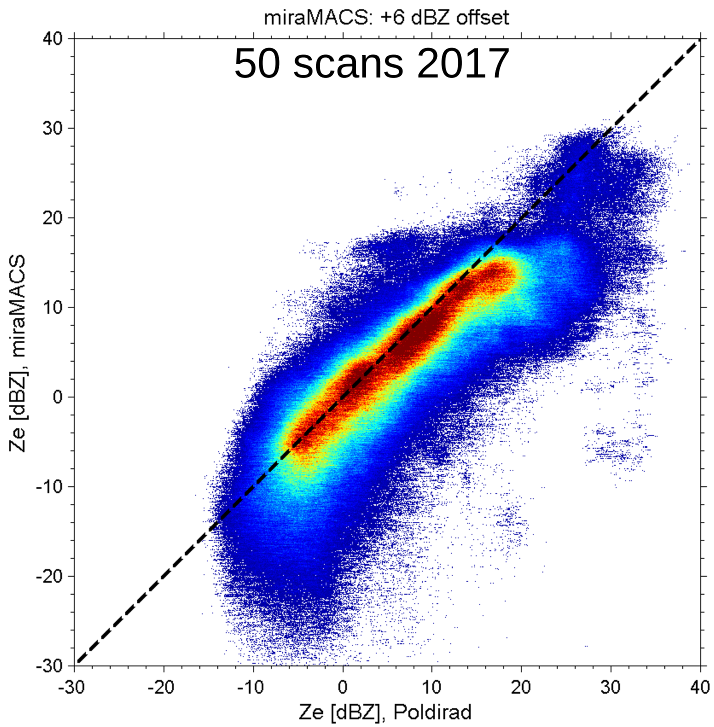


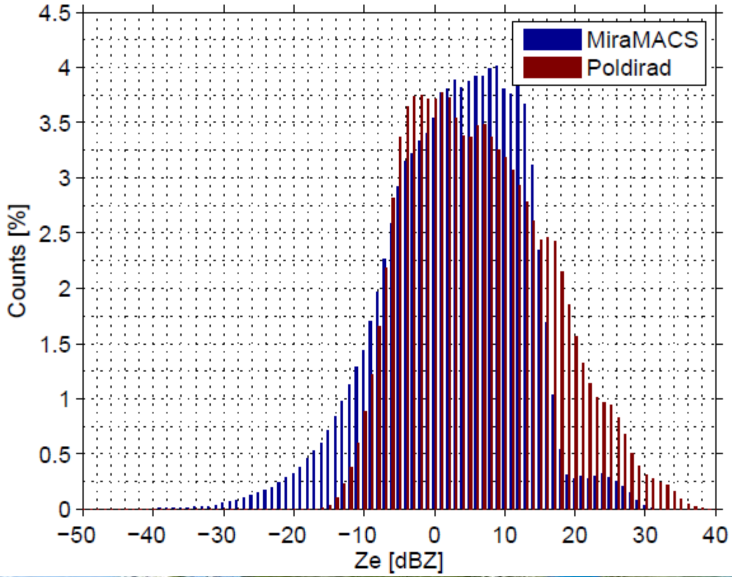
Sensitivity Issue – MDS

Minimum detectable/discernible signal (MDS):

- C-band POLDIRAD:
  (1 µs pulse, 64 samples)
  ~ -26 dB at 5 km
  ~ -17 dB at 15 km

- Ka-band miraMACS:
  (0.2 µs pulse, 256 samples)
  ~ -40 dB at 5 km
  ~ -31 dB at 15 km





Retrieval of Microphysical Properties of Ice Particles

Median volume diameter D_m

- dual-wavelength ratio
  $DWR = 58\ D_m^{1.66}$ (Matrosov, 1998)

Ice water content *IWC*

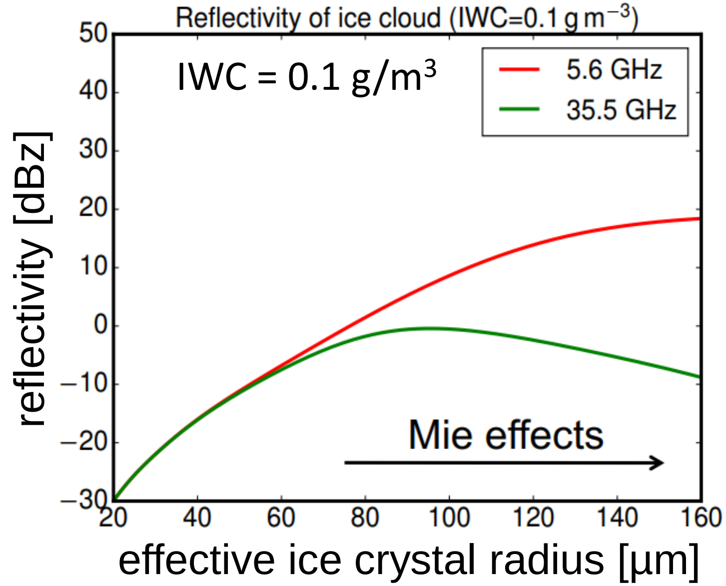
- e.g. Protat et al., 2007:
  $\log_{10}(IWC) = a \cdot Z \cdot T + b \cdot Z + c \cdot T + d$
  (T temperature, Z reflectivity Ka)

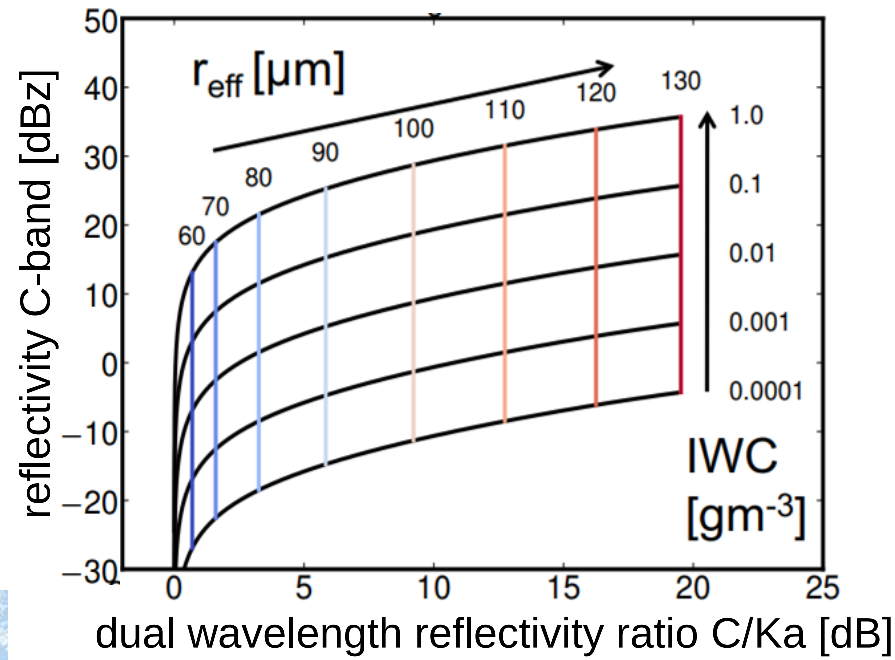
Particle shape and Particle size distribution

- look-up tables derived from T-matrix simulations

Effective radius r_{eff}

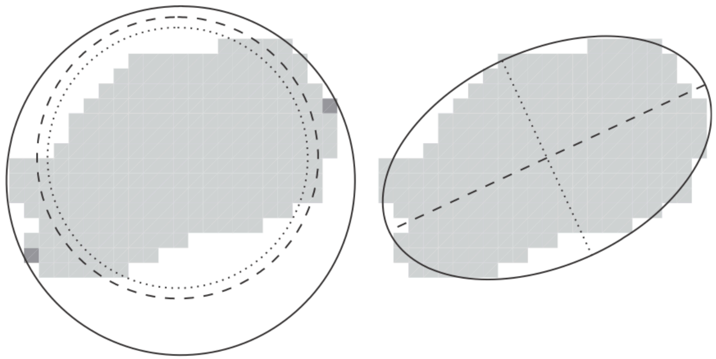
- known particle habits, *DWR*





T-Matrix Simulations of Ice Particle

Mass-size relationship



- spheroid approximation
  (Hogan et al., 2011)
- cylinder approximation
- aspect ratios 0.6, 1, 1.4
- mass approximation
  based on various world-wide field campaigns
  (Brown and Francis, 1995)

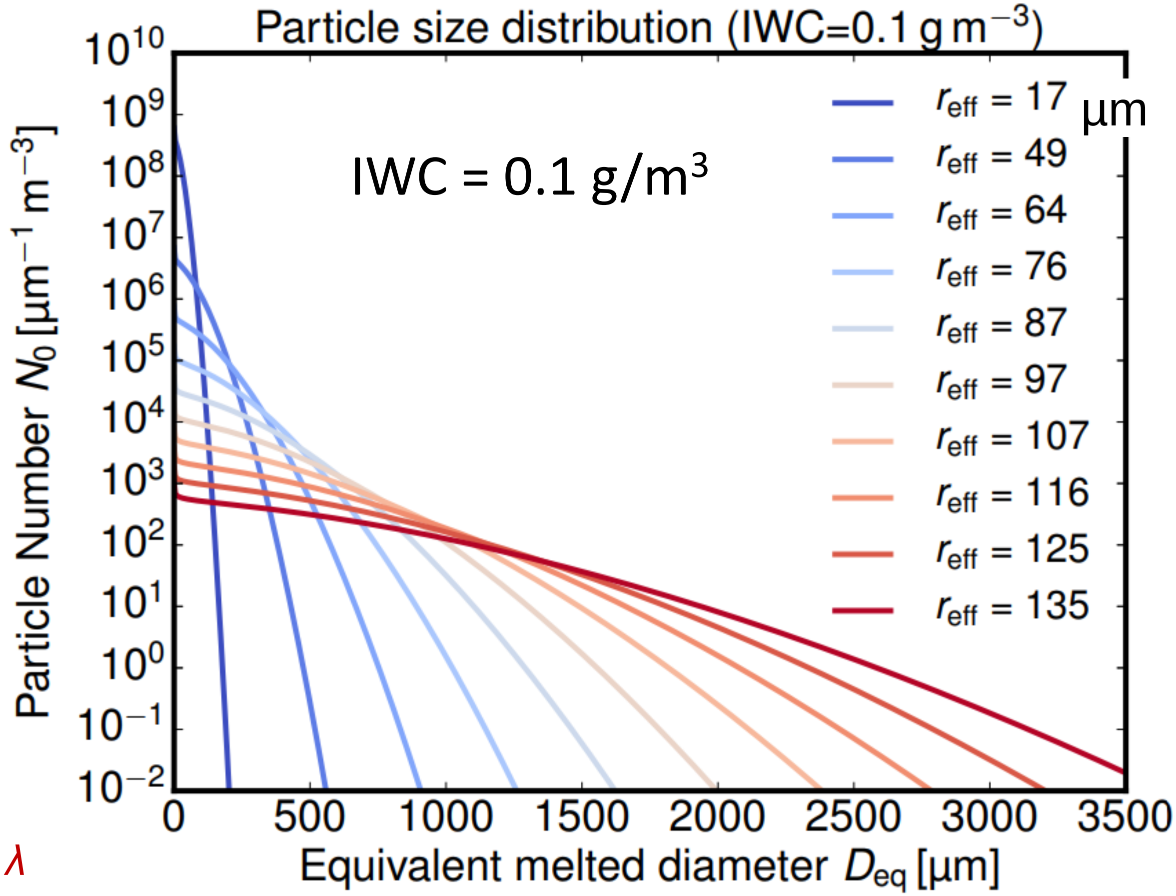
$$M(D) = 1.677\, e^{-1}\, D^{2.91} \qquad D <= 0.01 \text{ cm}$$
$$M(D) = 1.66\, e^{-3}\, D^{1.91} \qquad 0.01 < D <= 0.03 \text{ cm}$$
$$M(D) = 1.9241\, e^{-3}\, D^{1.9} \qquad D > 0.03 \text{ cm}$$

T-Matrix Simulations of Ice Particle

Particle size distribution

modified gamma function fitted to same in-situ data used for *M(D)* normalized by the volume-weighted diameter D_m and the intercept parameter N_0

(Delanoë et al., 2014)

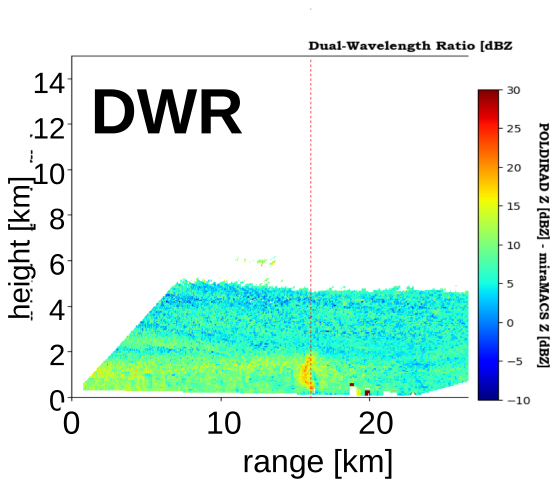


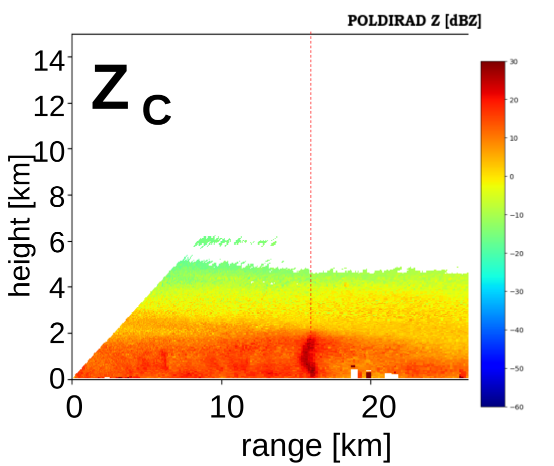
Effective radius

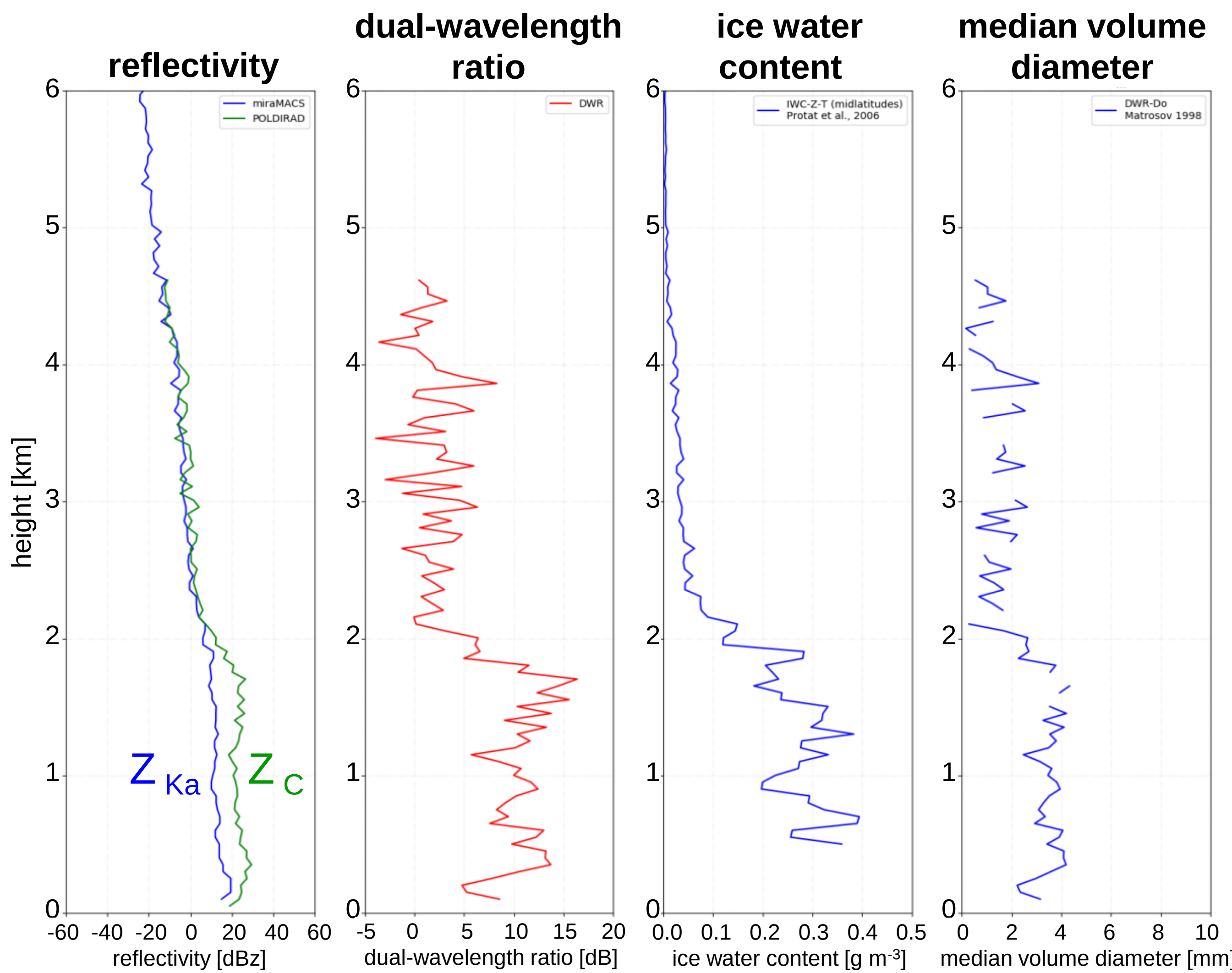
$$r_{eff} = \frac{m(3)}{m(2)} = \frac{\text{volume}}{\text{area}} \qquad r >> \lambda$$

Retrieval of Microphysical Properties of Ice Particles

Profile at 16 km (2019-01-09 12:09)





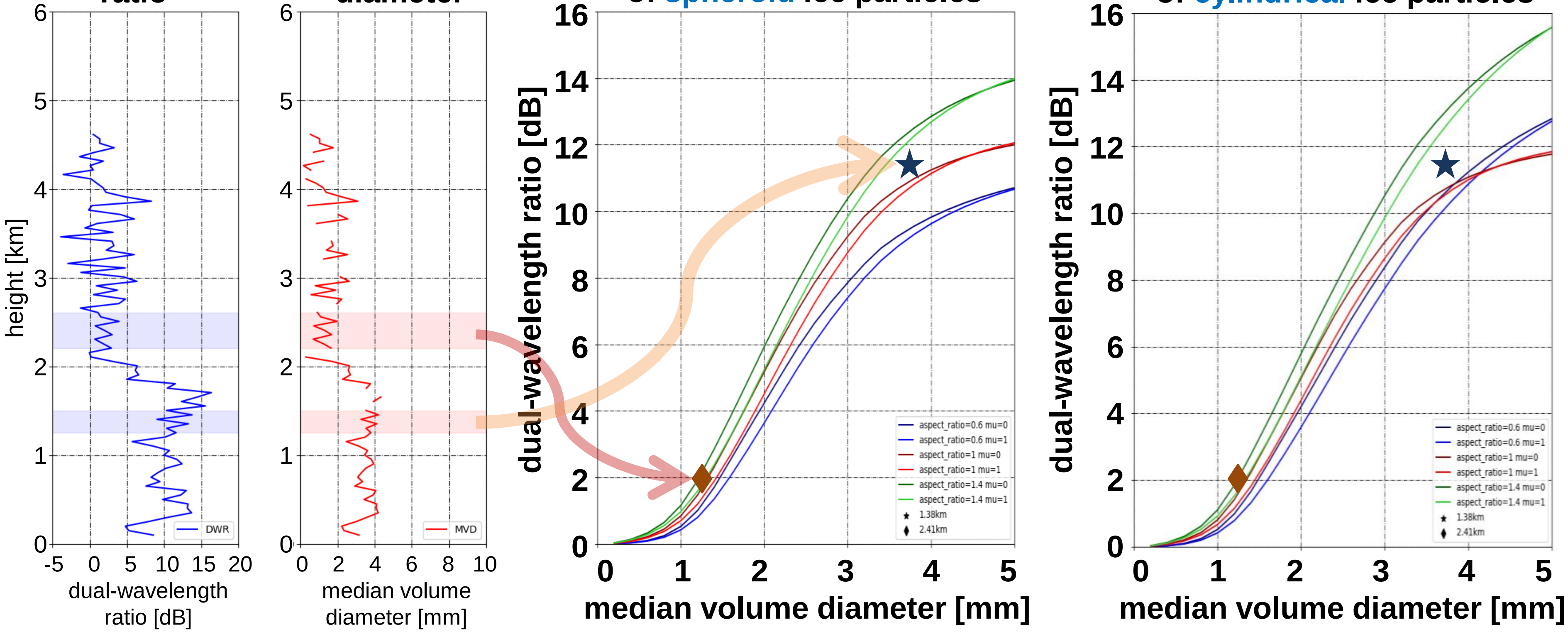


Retrieval of Microphysical Properties of Ice Particles

T-matrix simulations for spheroid and cylinder ice particles

- using different particle axis ratios: 0.6, 1, 1.4
- using different size parameters of a gamma size distribution: 0 and 1

dual-wavelength ratio | **median volume diameter** | **T-matrix simulations for Gamma distributions of spheroid ice particles** | **T-matrix simulations for Gamma distribution of cylindrical ice particles**



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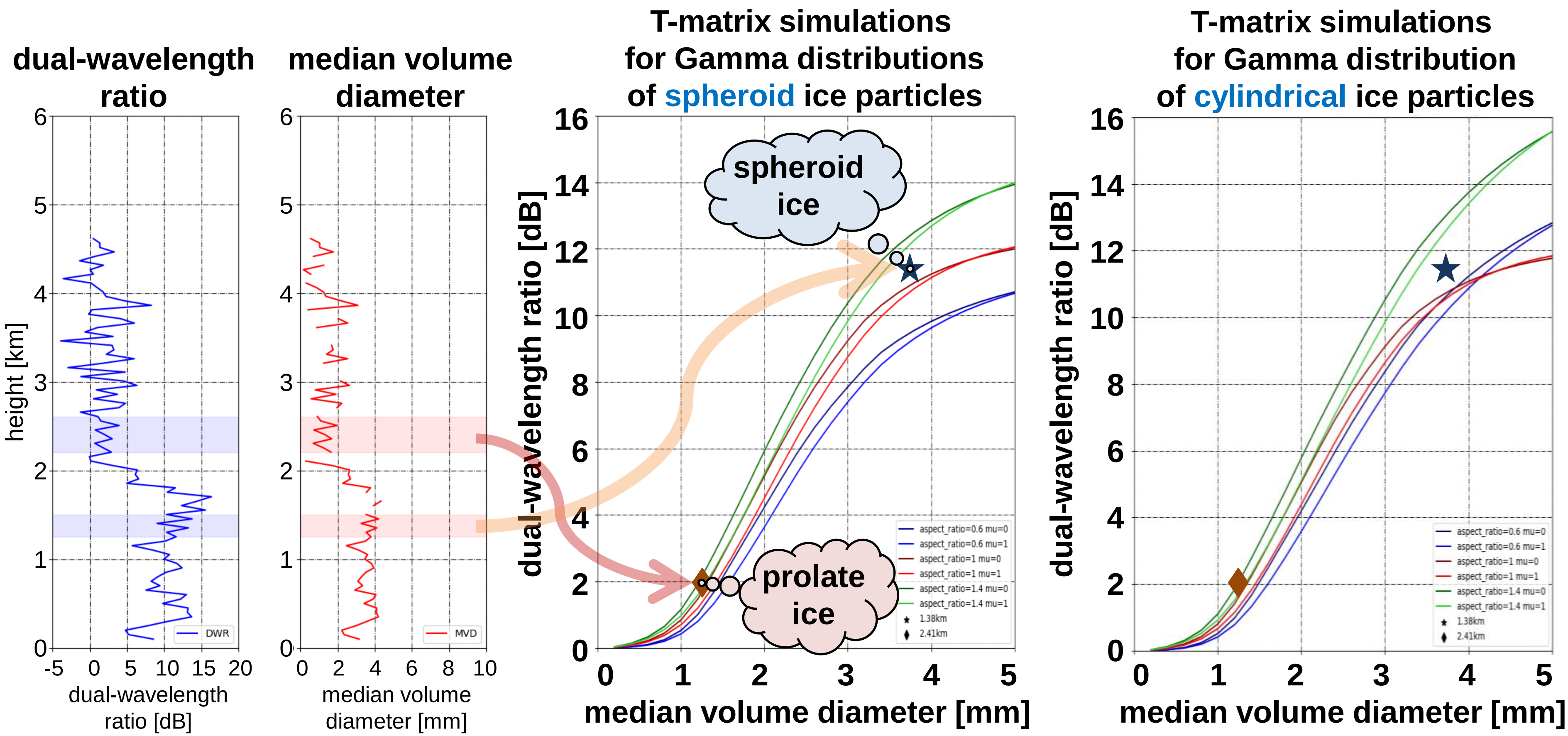

Multi-Wavelength Microphysics Retrieval

Dual-polarization C- and Ka-band Retrieval:

- reflectivity → ice water content IWC
- dual-wavelength reflectivity ratio → median volume diameter
  → effective radius of ice particles
  → particle habit through T-matrix simulations
- dual-polarization → hydrometeor classification
  → particle habit

The IcePolCKa project is sponsored within DFG SPP 2115 PROM

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