Spectrally resolved Polarimetric Observation and Computation of Clouds - SPOCC

PROM all-hands meeting 2024, 24-26 July 2024

PI's: Oswald Knoth (model), Patric Seifert (obs)

PhD's: Junghwa Lee (model), Majid Hajipour (obs)

Partners:

- Michael Frech (DWD)
- Herman Russchenberg (TU Delft)
- Alexander Myagkov (shape retrieval)
- Tempei Hashino (bin-spectral modelling)
- **Colleagues at TROPOS and LIM (Fabian Senf, Roland Schrödner, Heike Kalesse et al.)**

„Toward modeling and observing the hydrometeor ratio during the onset of precipitation."

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ACCEPT

Universität Bonn DFG

Polarimetric Radar Observations meet Atmospheric Modelling

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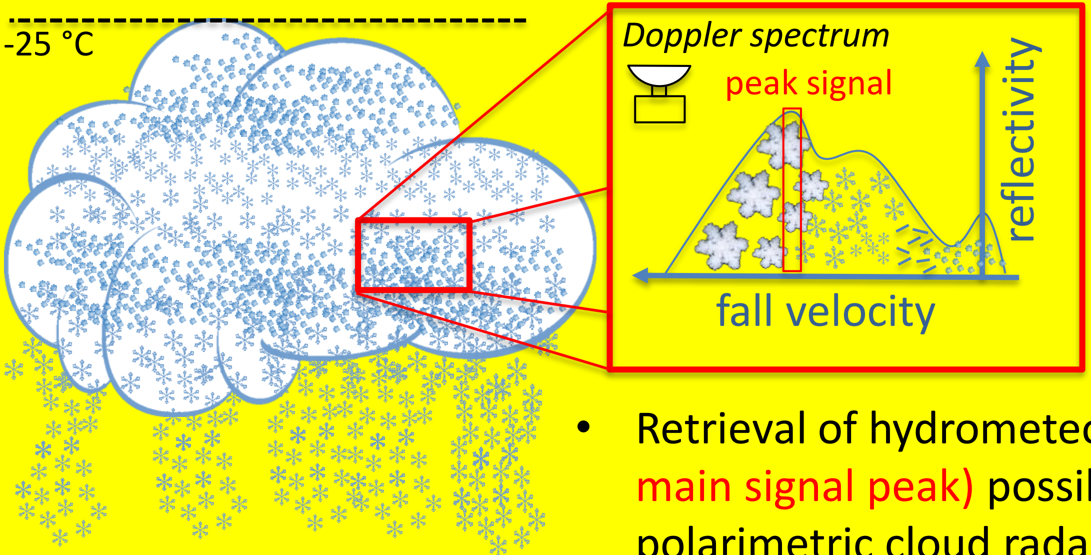
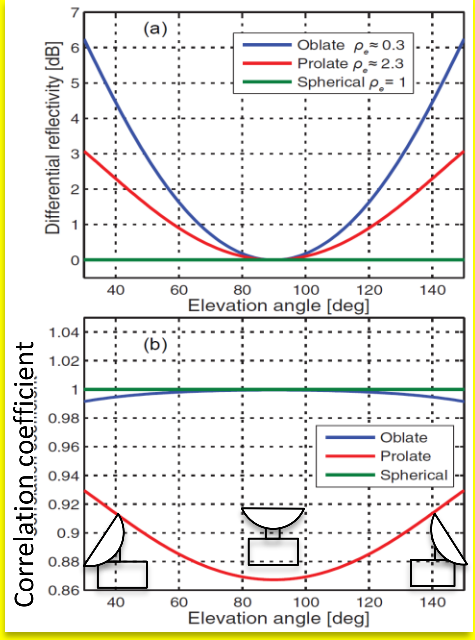
SPOCC: Motivation

- Mixed-phase processes involve different types/habits of hydrometeors
- Modeling: Hydrometeor habits need to be distinguishable → Part 1
- Observation: Cloud radars required to reach sensitivity needs → Part 2



Polarimetry + RHI Scans

- Retrieval of hydrometeor habit (of main signal peak) possible from polarimetric cloud radar RHI scans *(Myagkov et al., 2015, AMT)*



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Goal of the project (SPOCC)

1. (O,M) Development of a spectral polarimetric analysis technique to identify multiple hydrometeor types in a measurement volume and the corresponding reflectivity-weighted hydrometeor ratio from polarimetric Doppler cloud radar measurements.

2. (M) Advance spectral-bin microphysical modeling to understand the pathways from heterogeneous ice formation towards the evolution of cloud microphysical properties

3. (M,O) Check if the observations are accurate enough to be valuable for model evaluation. Check if the simulations are accurate enough to help interpreting observations.

(O: Observation, M: Modeling)

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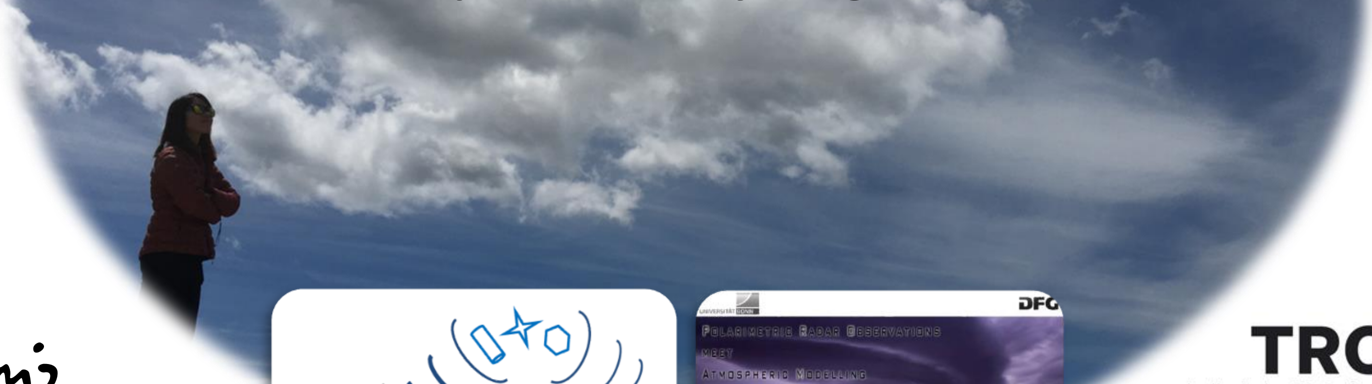
Spectrally Resolved Polarimetric Observation and Computation of Clouds (SPOCC)

Part I:

Assessment of the impact of CCN and INP perturbations on mixed-phase clouds using a spectral-bin model

Work performed by Junghwa Lee



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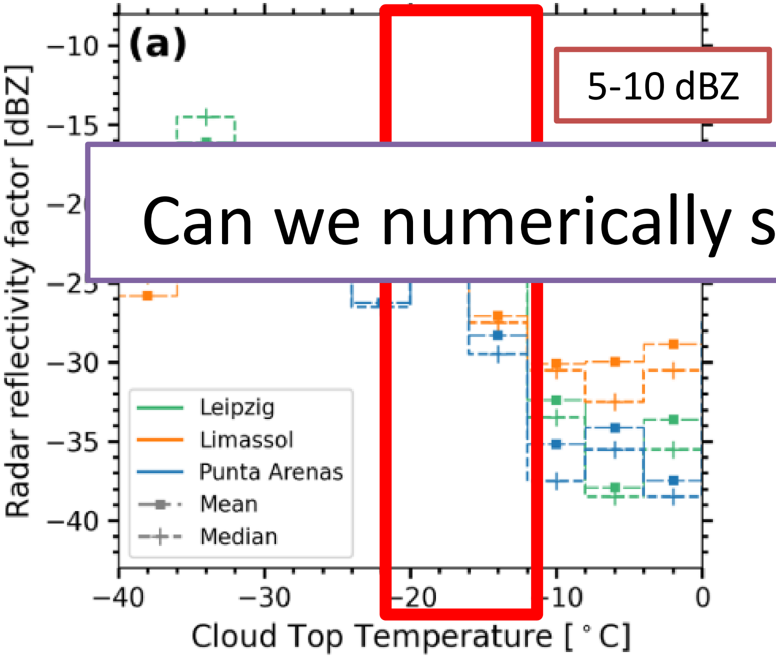
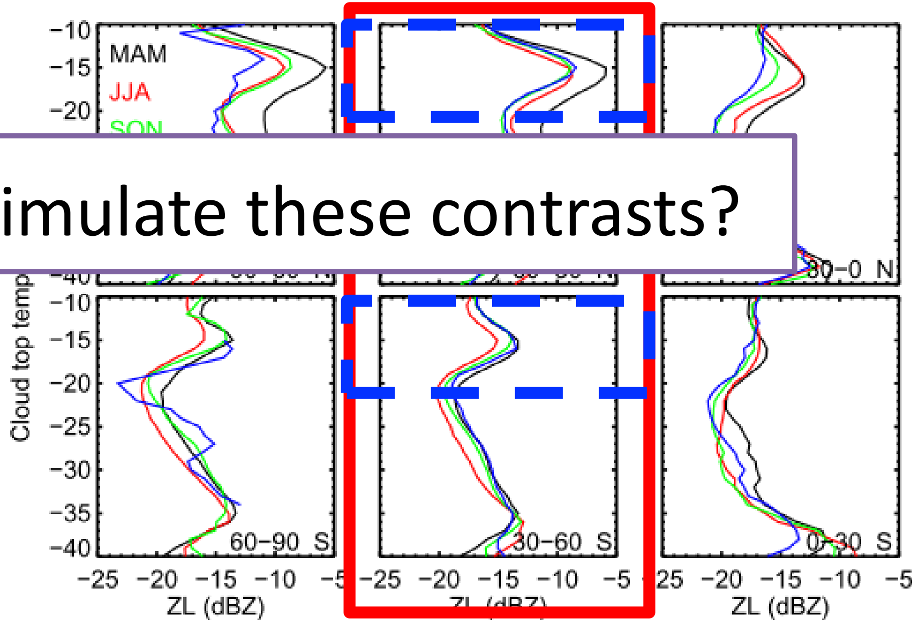
Lee et al., 2024, Atmos. Chem. Phys., 24, 5737–5756, https://doi.org/10.5194/acp-24-5737-2024 ,

Analysis of aerosol-related contrasts in cloud-radar reflectivities observed in stratiform supercooled mixed-phase clouds

Radenz et al. (2021), ACP



Zhang et al. (2018), ACP



Can we numerically simulate these contrasts?

Lee et al., 2024, Atmos. Chem. Phys., 24, 5737–5756, https://doi.org/10.5194/acp-24-5737-2024 ,

The spectral-bin microphysics model

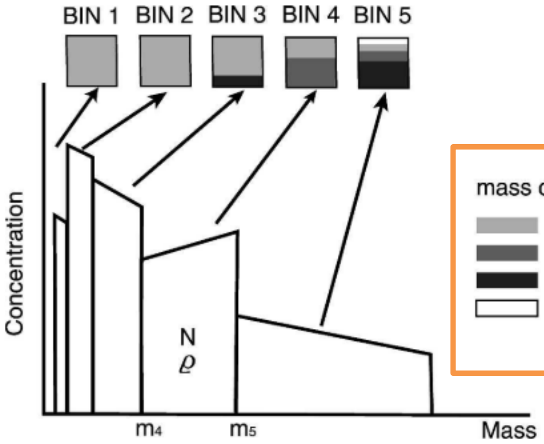
→ Advanced Microphysical Prediction System (AMPS; Hashino and Tripoli (2007), JAS)

18 prognostic variables / bin

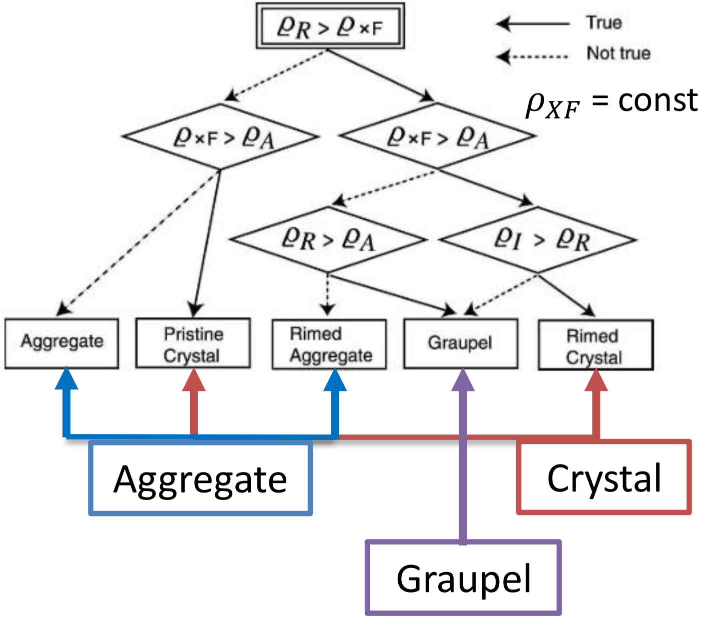
Mass ρ
Concentration N

+

Particle Property Variables (PPVs)



mass content components
- ice crystal mass, ρ_I
- aggregate mass, ρ_A
- rime mass, ρ_R
- melt-water mass, ρ_W
- frozen mass, ρ_f



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Lee et al., 2024, Atmos. Chem. Phys., 24, 5737–5756, https://doi.org/10.5194/acp-24-5737-2024 ,

Numerical evidence that the impact of CCN and INP concentrations on mixed-phase clouds is observable with cloud radars (Lee et al., 2023, preprint)

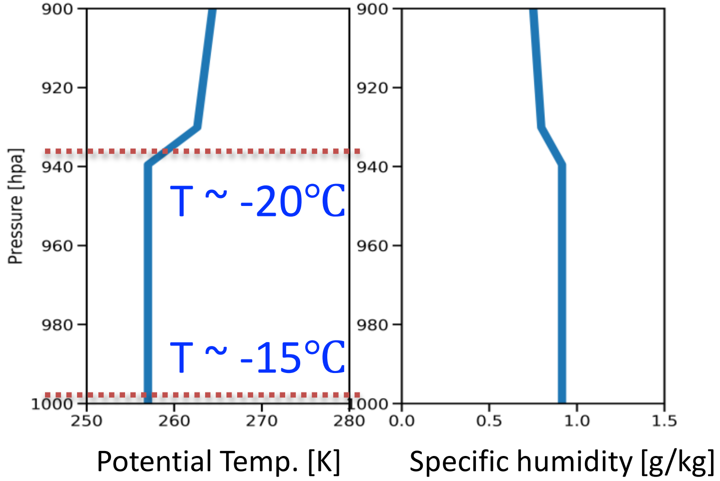
- Simulations with AMPS for the same thermodynamical condition of stratiform supercooled liquid cloud, but strongly different aerosol conditions

Pristine (→ CCN Mid) | Polluted (→ CCN High)

Typical Arctic mixed-phase clouds (→ INP Mid)

		CCN		
		Low 10 cm^{-3}	Mid 50 cm^{-3}	High 500 cm^{-3}
INP	Low 0.001 L^{-1}		EXP3	
INP	Mid 0.1 L^{-1}	EXP4	EXP2 (Control)	EXP5
INP	High 10 L^{-1}		EXP1	

- Initial condition



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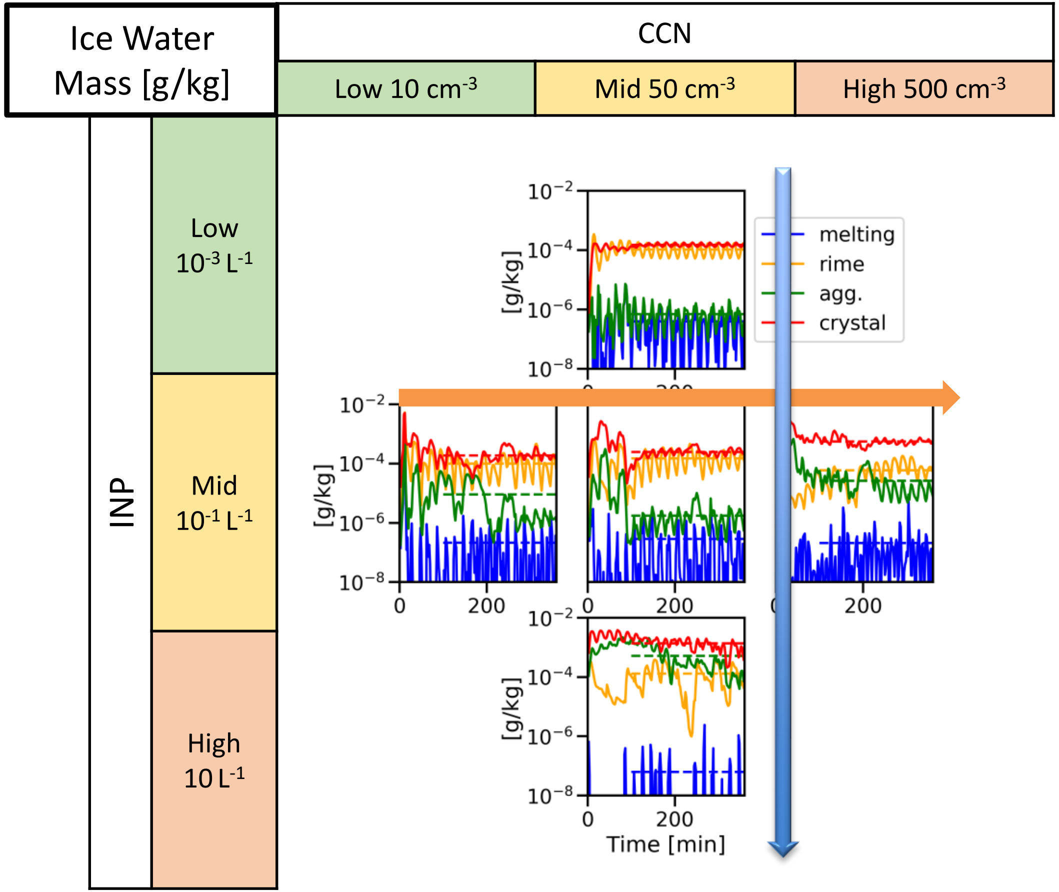
Lee et al., 2024, Atmos. Chem. Phys., 24, 5737–5756, https://doi.org/10.5194/acp-24-5737-2024 ,

Simulation results of AMPS



- CCN concentration ↑
  → slightly ↑ aggregation
  → ↓ Riming

  Reduction in the size of supercooled liquid particles available for riming

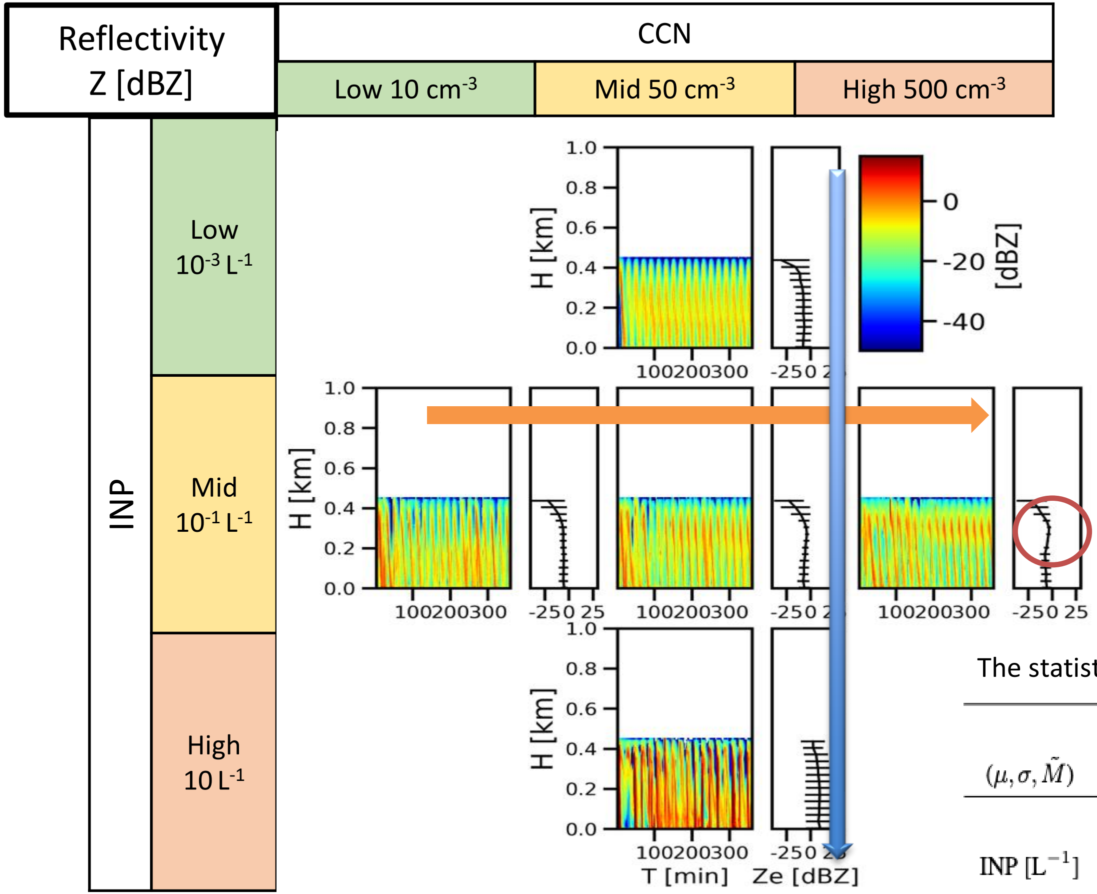
  (Borys and Lowenthal, 2003, GRL)

- INP concentration ↑
  → ⬆ Aggregation and ⬆ Crystal
  → ↓ Riming

  Reduction in the number of supercooled liquid particles available for riming

Lee et al., 2024, Atmos. Chem. Phys., 24, 5737–5756, https://doi.org/10.5194/acp-24-5737-2024 ,

Radar Reflectivity factor from AMPS-PAMTRA (Ka-band)



- SSRGA method (Self-Similar Rayleigh–Gans Approximation)
  (Maherndl et al., 2023, accepted)
- CCN concentration ↑
  → Z similar
  → ↓ standard deviation
- INP concentration ↑
  → ↑ Z
  → Consistent with the observation findings
  (Zhang et al., 2018, Radenz et al., 2021)

The statistical analysis of radar reflectivity factor Z [dBZ]

$(\mu, \sigma, \tilde{M})$		CCN $[cm^{-3}]$ 10	50	500
INP $[L^{-1}]$	0.001		(-11.83, 9.12, 0.36)	
	0.1	(-10.23, 5.70, 1.63)	(-10.09, 5.60, 1.19)	(-9.87, 5.05, 1.71)
	10		(4.65, 12.47, 2.87)	

Part 2: Identification of hydrometeor types in Doppler spectra from polarimetric cloud radar

Spectrally resolved Polarimetric Observations and Modelling of Clouds (SPOMC)

Work performed by Majid Hajipour

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• Introduction of measurement site

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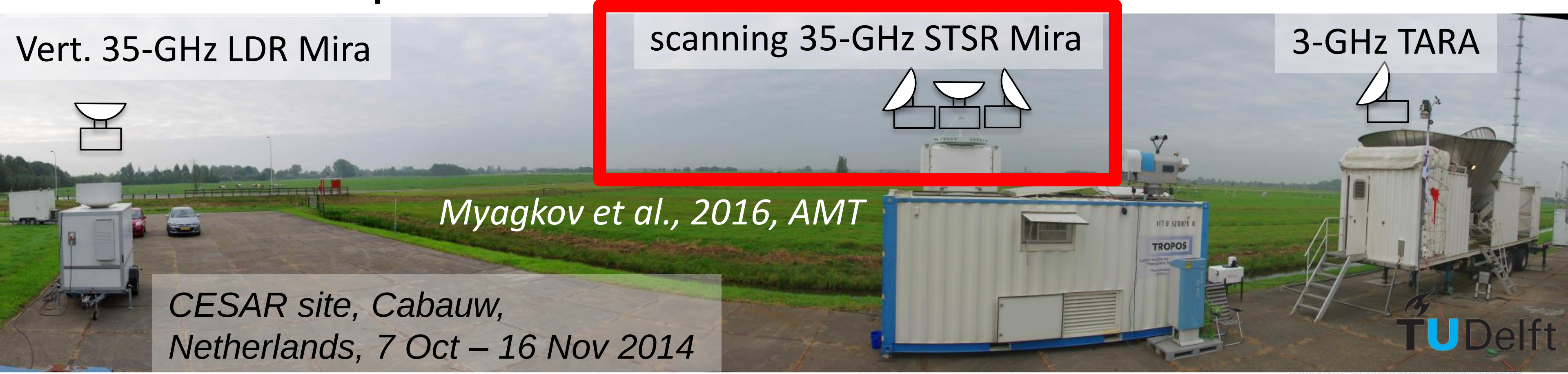
Analysis of the Composition of Clouds with Extended Polarization Techniques

- 6-week measurement campaign at CESAR obs., Cabauw
- Vert. pointing LDR-mode Mira-35 (TROPOS)
  + Lidars, MWR, Doppler lidar, wind profiler, radiosondes
- **Scanning STSR-mode Mira-35 (TROPOS/Metek)**
- Tilted full polarimetric S-band TARA (TU Delft)



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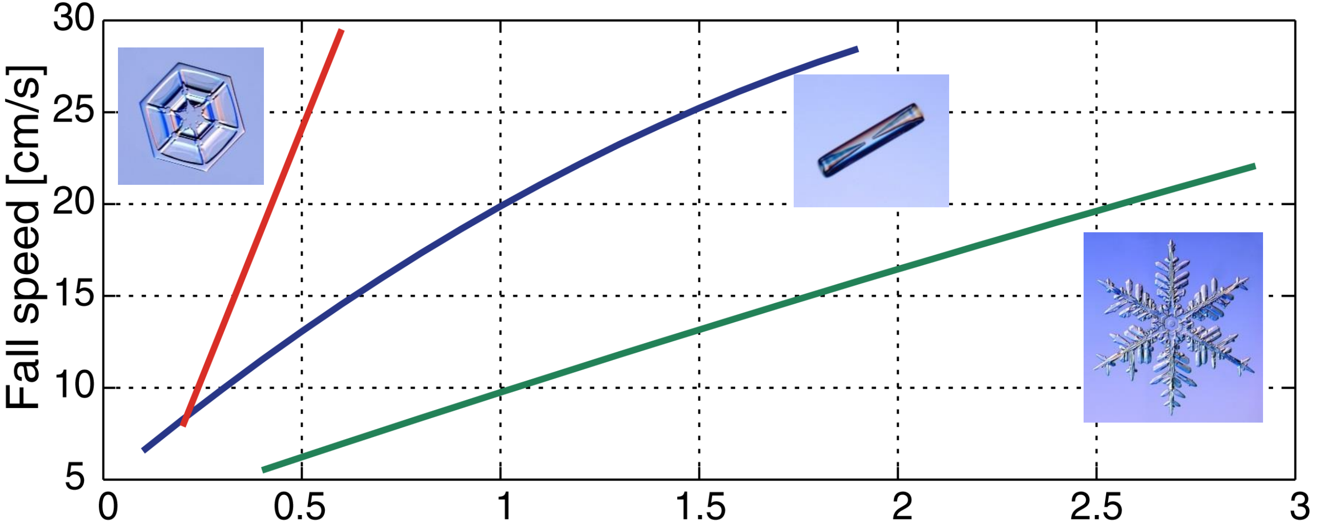
• Relation of fall speed and shape

Particles of different shape are characterized by different fall velocities



Prof. Takahashi

- Concentration: <100 cm^{-3}

Shape and orientation retrievals → **Particle's size and aspect ratio**

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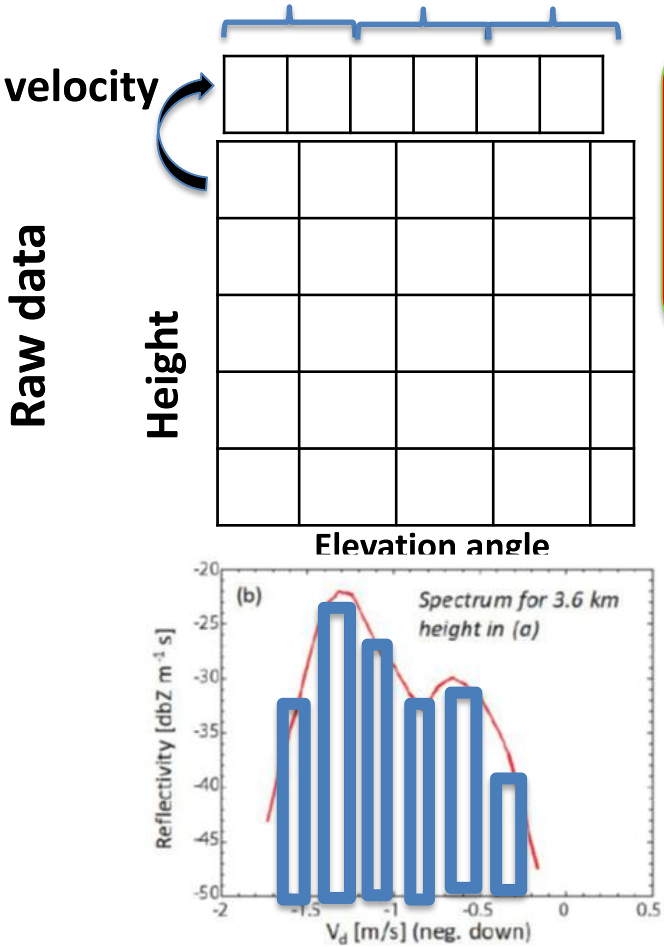
Goal of SPOCC: Extension of Myagkov 2016 (AMT) shape retrieval approach



Modeling

Simulation of polarimetric variables ZDR and ρ_{hv} for different values of shape and orientation

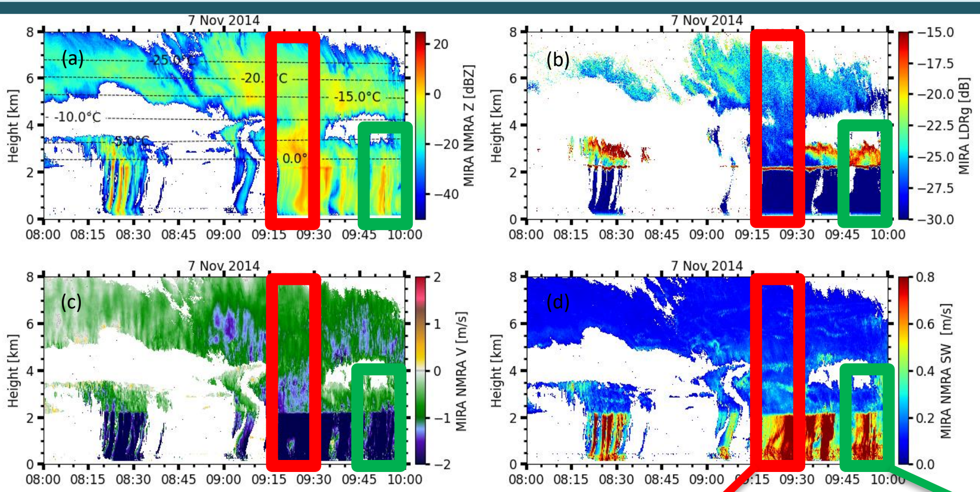
Observation

Splitting Doppler spectrum into n bins for each pair of height and elevation angle

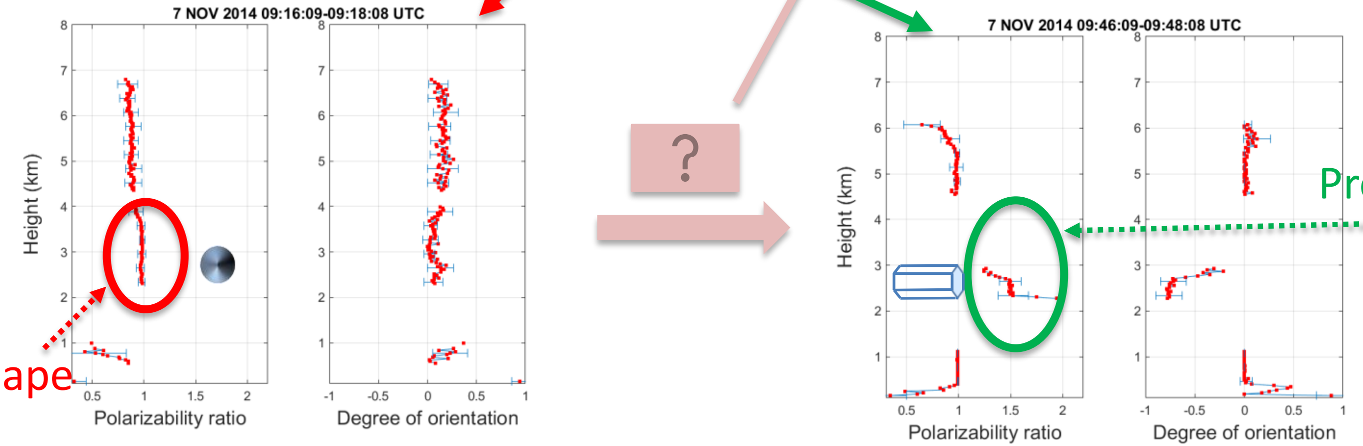
Comparing observed and modeled ZDR and ρ_{hv} to find closest one. (using minimum mean square error)

Shape & orientation

Case study : 7 November 2014, 09:15 - 09:30 UTC, Cabauw, NL: Only meain-peak retrieval



Why does shape of the ice particles change from isometric to prolate?

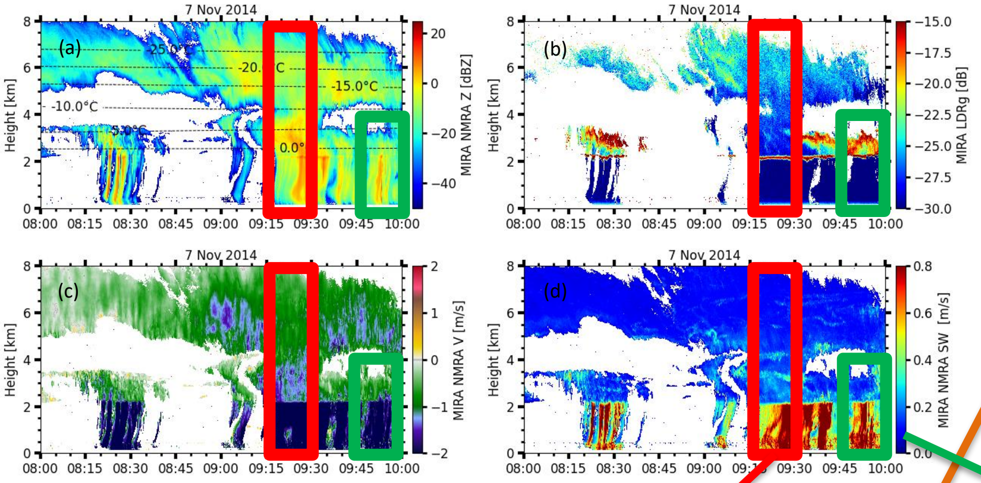


?

Prolate shape

Isometric shape

Shape retrieval results obtained by spectrally resolved approach



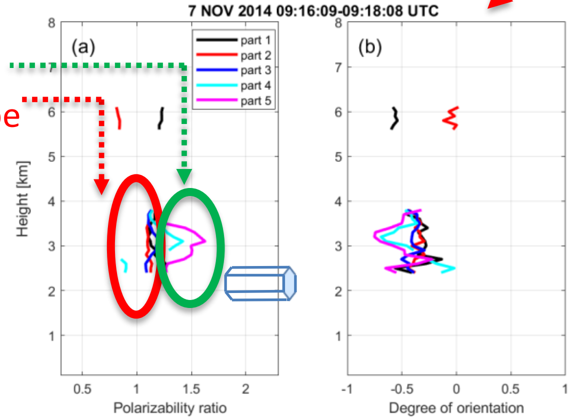
Why does shape of the ice particles change from isometric to prolate?

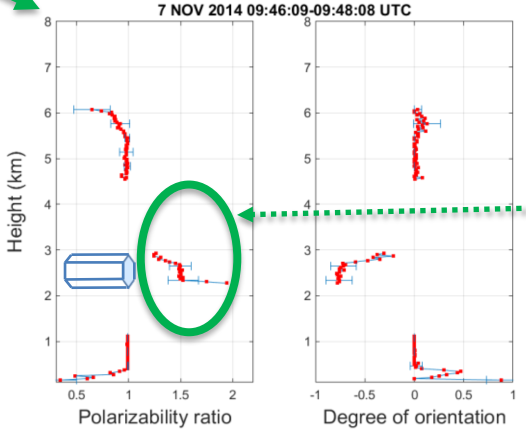
Prolate particles already present in first (red) part of the observation!

Spectrally-resolved shape retrieval required for identifiation

Prolate shape

Isometric shape





Prolate shape

Majid Hajipour, Hajipour@tropos.de

Summary and Conclusions

(O: Observation, M: Modeling)

1. (O,M) Development of a spectral polarimetric analysis technique to identify multiple hydrometeor types in a measurement volume and the corresponding reflectivity-weighted hydrometeor ratio from polarimetric Doppler cloud radar measurements.

→ Dissertation thesis Hajiour, M., submitted to University of Leipzig in June 2024

✓ → Two articles in preparation:

- Spectrally resolved shape and orientation retrieval technique
- Application of the retrieval to interprete low-lidar-LDR events in mixed-phase clouds

2. (M) Advance spectral-bin microphysical modeling to understand the pathways from heterogeneous ice formation towards the evolution of cloud microphysical properties

✓ → Lee et al., 2024, Atmos. Chem. Phys.,https://doi.org/10.5194/acp-24-5737-2024

→ Dissertation thesis in preparation

3. (M,O) Check if the observations are accurate enough to be valuable for model evaluation. Check if the simulations are accurate enough to help interpreting observations.

– → No suitable case could be identified which allowed to compare observed and simulated particle habit distributions

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