Spectrally resolved Polarimetric Observation and Computation of Clouds - SPOCC

PROM 2nd annual meeting, 15-16 October 2020

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

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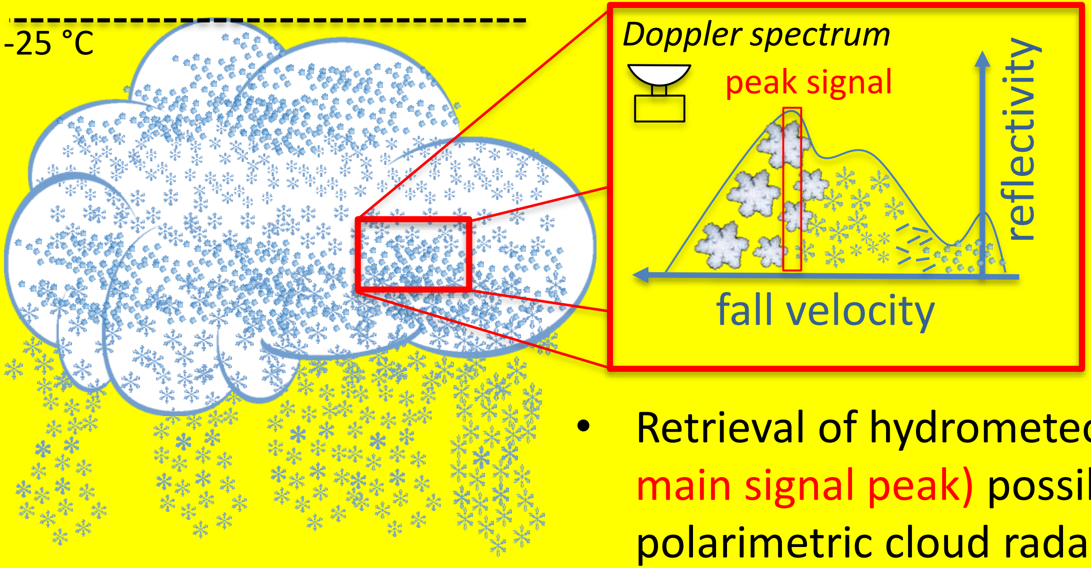
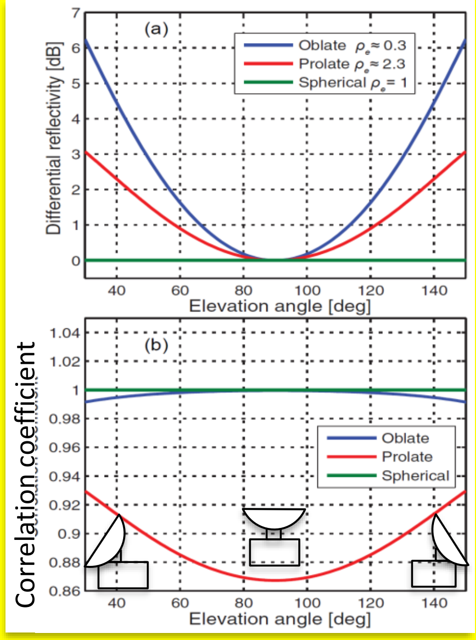
SPOCC: Motivation

- 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)

TROPOS

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

Fabian Senf on behalf of Junghwa Lee

PROM Meeting

16.10. 2020

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Polarimetric Radar Observations meet Atmospheric Modelling
PROM

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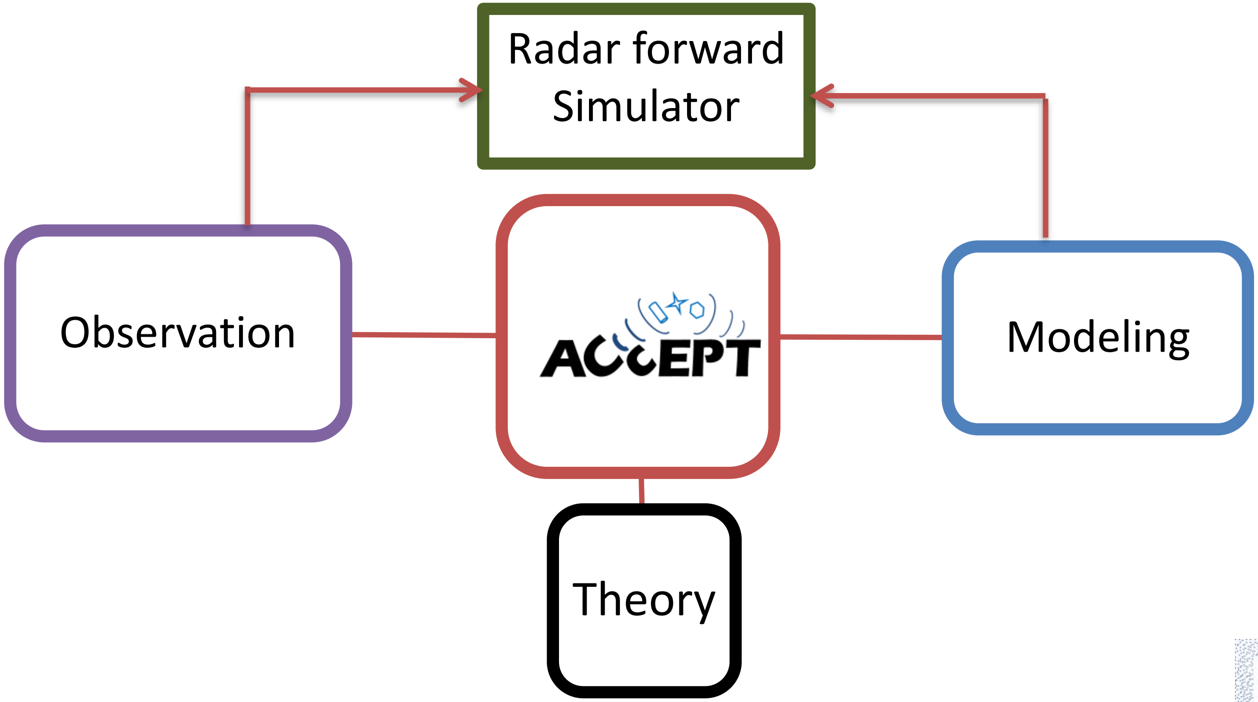
❑ Combining polarimetric radar observations and microphysics models

- CR-SIM
- PAMTRA



- Polarimetric 35GHz Radars
- Disdrometer
- X-band radar
- Radiosondes
- Wind profiler
- Doppler lidar
- MWR

- SPECS
- AMPS

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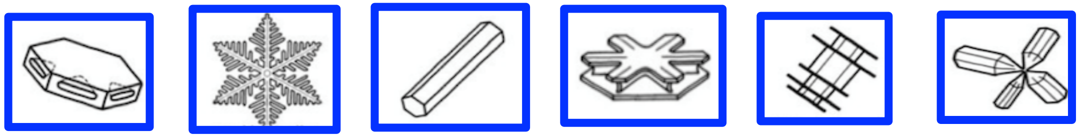
The motivation of advanced microphysics modeling: Spectral-bin model

→ Advanced Microphysical Prediction System (AMPS; Hashino et al. (2020), JAS)



- **Hydrometeor shapes** treated separately and influence precipitating formation differently

TROPOS

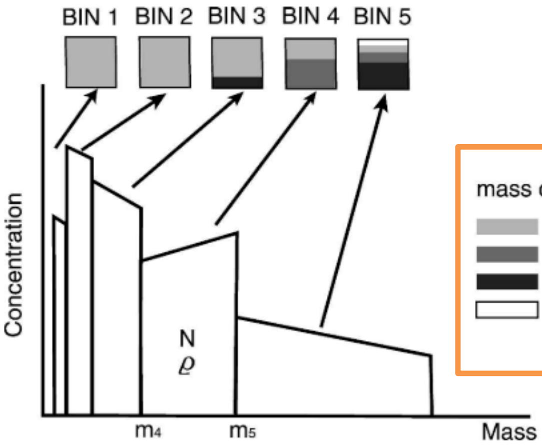
The motivation of advanced microphysics modeling: Spectral-bin model

→ Advanced Microphysical Prediction System (AMPS; Hashino et al. (2020), JAS)

16 prognostic variables per bin

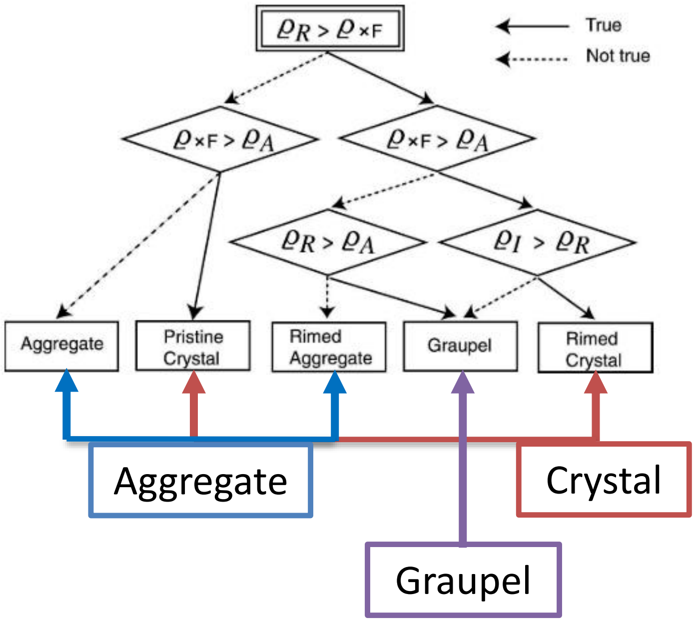
Mass ρ
Concentration N

Particle Property Variables



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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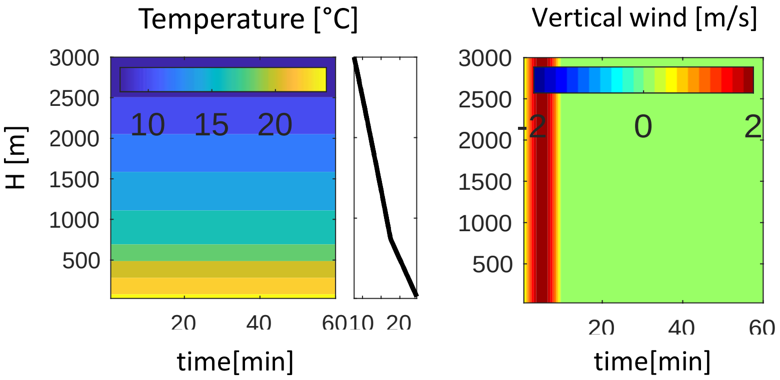
Evaluation of the spectral-bin model

- We tested the AMPS in **Ki**nematic Driver **M**odel (**KiD**) framework (Shipway and Hill, 2012, QJRM)

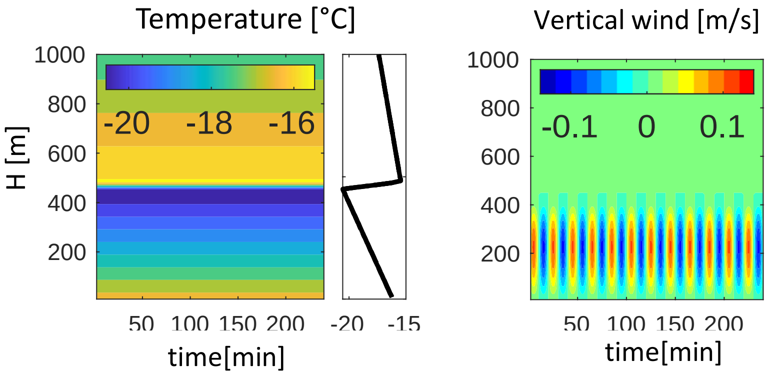
TEST 1: Warm clouds

$$w(z,t) = \begin{cases} w_1 \sin(\pi t/t_1), & \text{if } t < t_1, \\ 0.0, & \text{if } t > t_1, \end{cases}$$



TEST 2: Mixed-phase stratocumulus

$$w(z,t) = \begin{cases} w_1 \dfrac{z}{z_6}\left(1 - \exp\left[-\left(\dfrac{z-z_6}{z_2}\right)^2\right]\right) \sin(\pi t/t_2), & \text{if } z < z_6, \\ 0.0, & \text{otherwise}, \end{cases}$$



Result Part 2:
The impact of CCN and INP perturbations on mixed-phase clouds

- Simulations with AMPS for the same thermodynamical condition but strongly different aerosol conditions

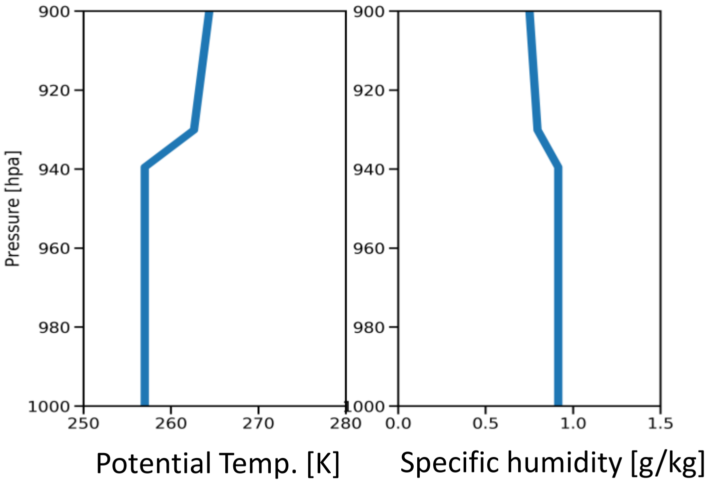
Pristine → CCN Mid; Polluted → CCN High

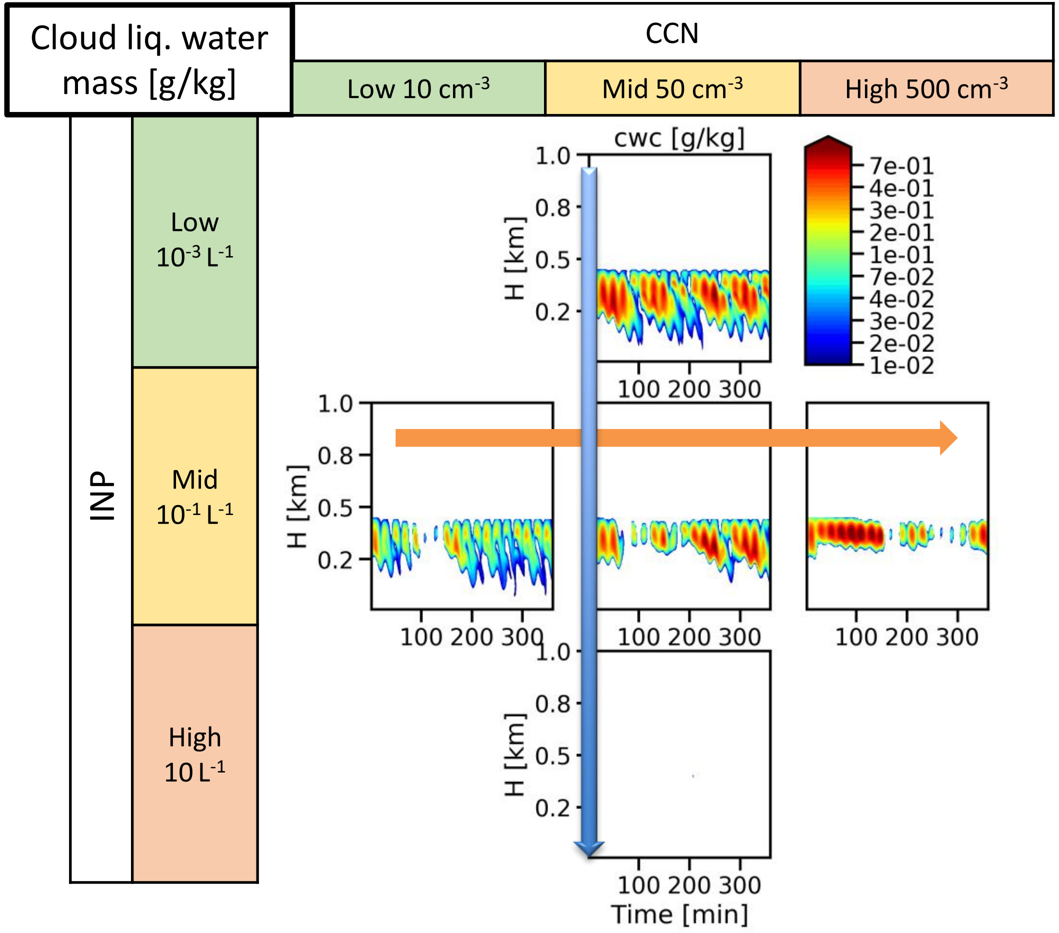
Typical Arctic mixed-phase clouds → INP Mid

		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	

CCN: Cloud Condensation Nuclei
INP: Ice Nucleating Particle

- Initial condition





- CCN concentration ↑
  → cloud liquid water mass ↑
  → suppresses precipitation
- INP concentration ↑
  → cloud liquid water mass ↓

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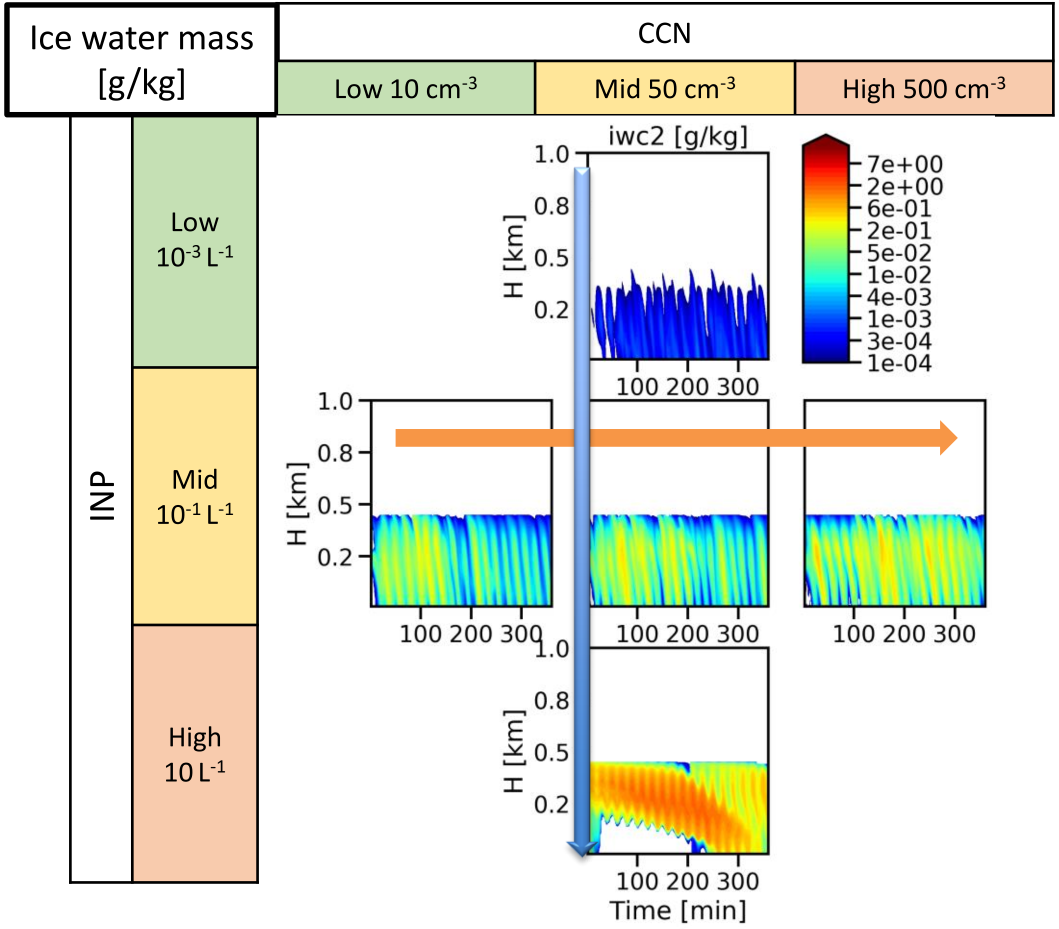

- CCN concentration ↑
  → Ice water mass ↑

- INP concentration ↑
  → Ice water mass ↑

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Conclusions: Impact of INP and CCN perturbations on mixed-phase clouds

- As CCN increases, cloud water mass increases.
- Also, increasing INPs enhances ice water mass.

- Increasing INPs leads to increased aggregation.
- Increasing CCN slightly enhances aggregation.
- But, it doesn‘t show a clear relationship between CCN concentrations and the riming.

- Immersion freezing is the dominant ice nucleation pathway.
  Observation studies also argue that.
  (Ansmann et al, 2009; de Boer et al., 2011; Hande et al., 2017; Wiacek et al., 2020)
- Contact freezing is also essential in the presence of high INP conditions.

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Outlook

Improve microphysics model

- Particle shape comparison
- The AMPS will be coupled with COSMO
- Update terminal fall velocity
- Simulation of ACCEPT case studies

- Coupling of the CR-SIM with the AMPS
- Extension of aspect ratio representation

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

Spectrally resolved Polarimetric Observations and Modelling of Clouds (SPOMC)

Majid Hajipour

16th of October 2020
PROM meeting

Leibniz Association

ACCEPT

DFG

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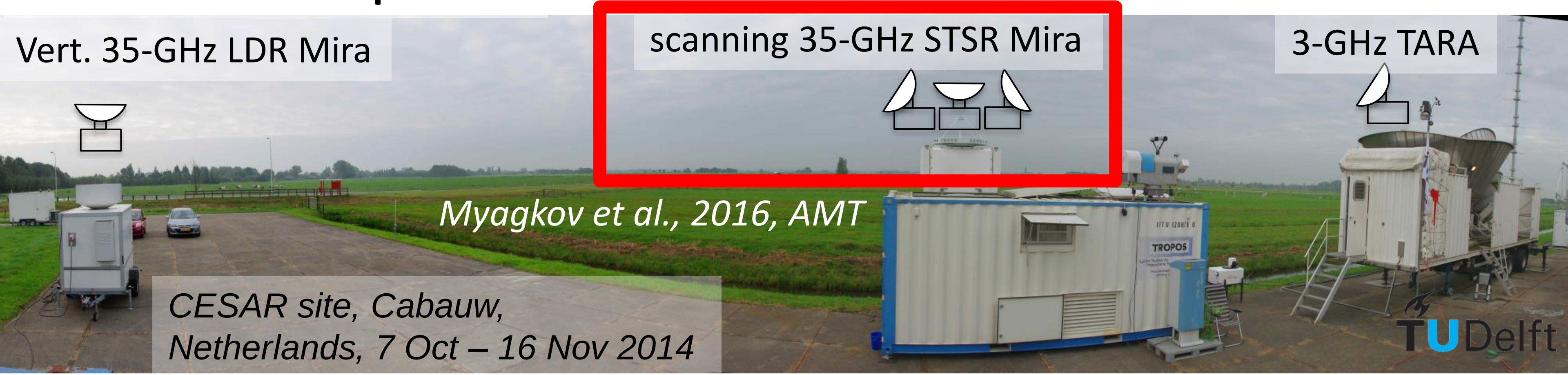
• Introduction of measurement site

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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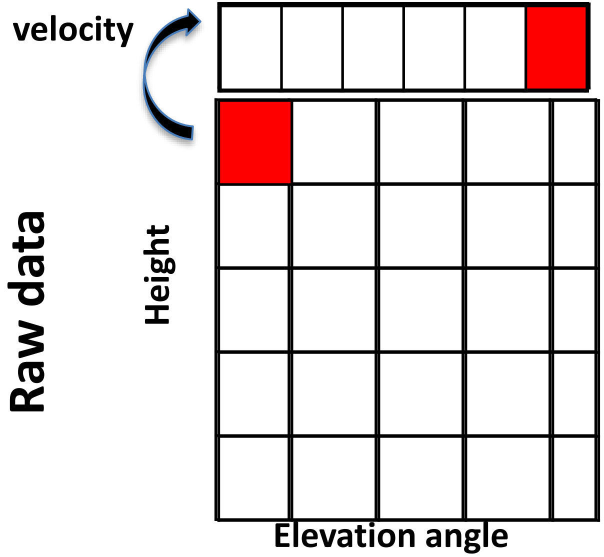
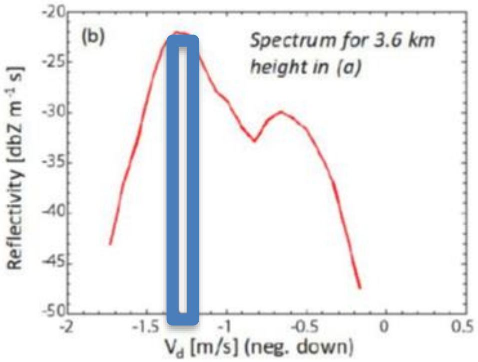
Original shape retrieval approach: Main peak of Doppler spectrum





Modeling

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

Observation

Selecting main peak of doppler spectrum for each pair of height and elevation angle

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

Shape & orientation

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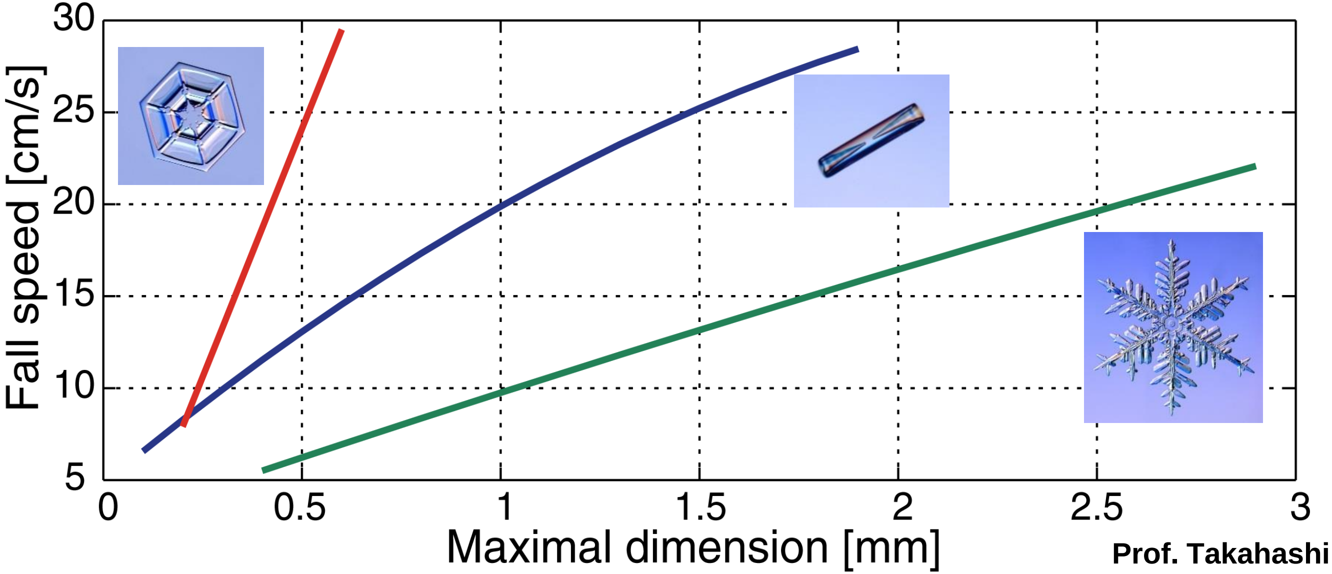
• Relation of fall speed and shape

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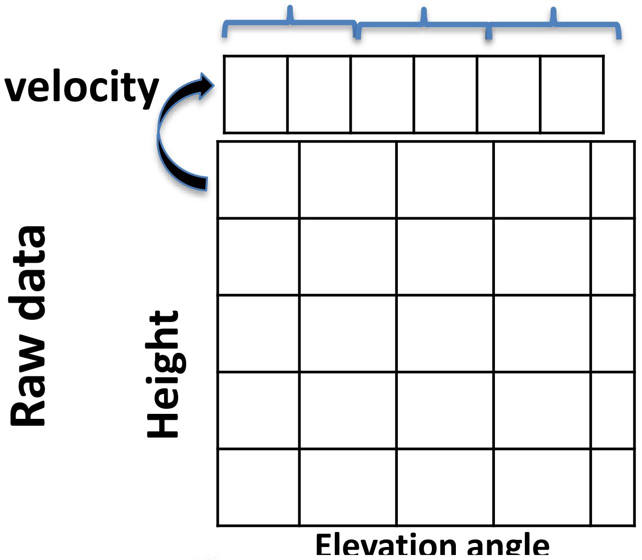
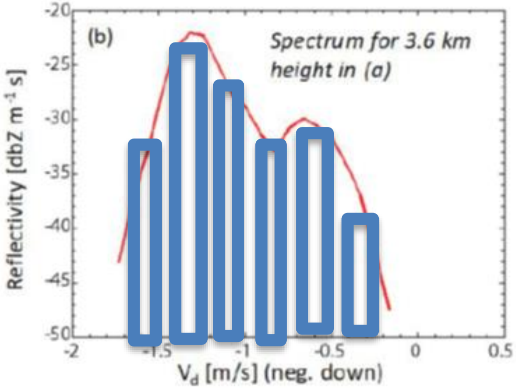
Goal of SPOCC: Extension of Myagkov 2016 (AMT) shape retrieval approach





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

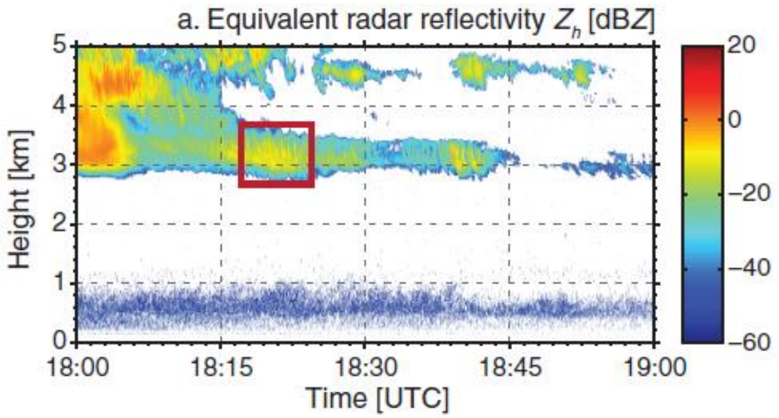
Case study:

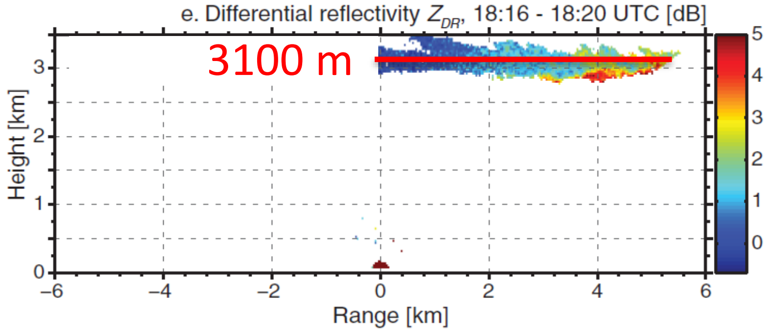
- ❑ Doppler spectrum is available for every data point (range, height/elevation)
- ❑ **Splitting Doppler spectra of RHI scan into 5 parts**

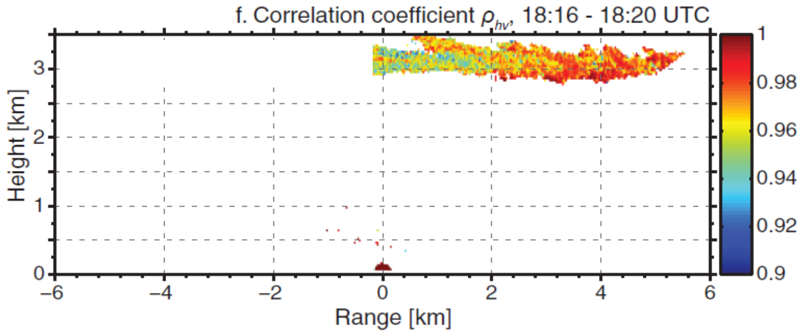
Date: 2014-10-20

Time: 18:15 UTC

Height: 3100 m







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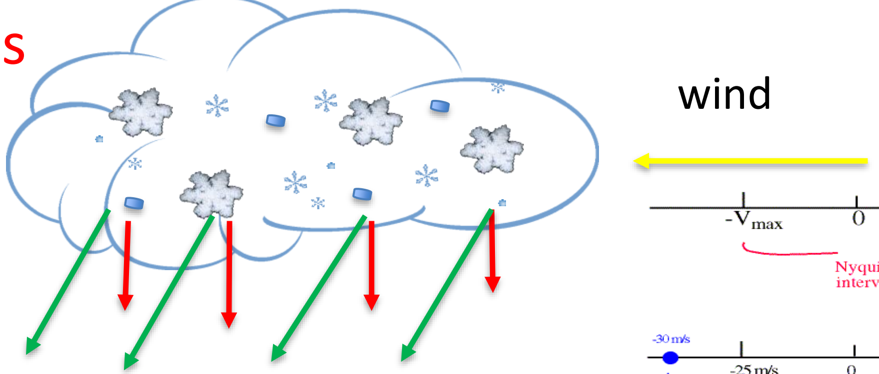
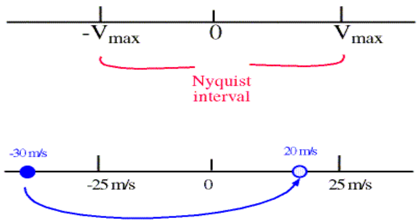
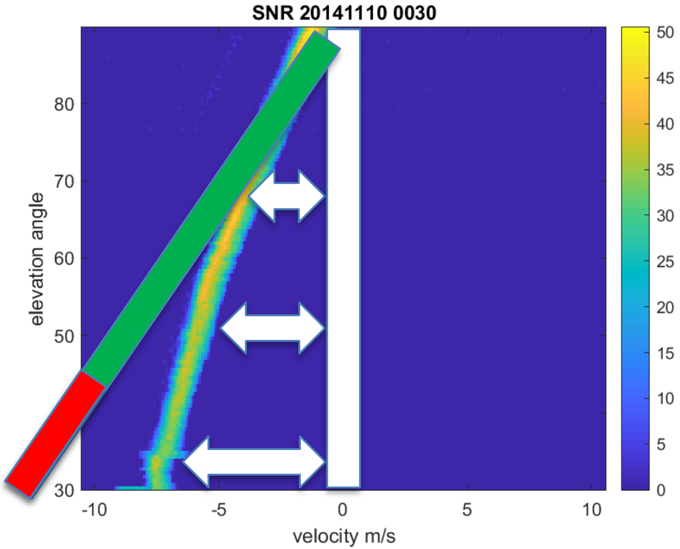
Wind effects

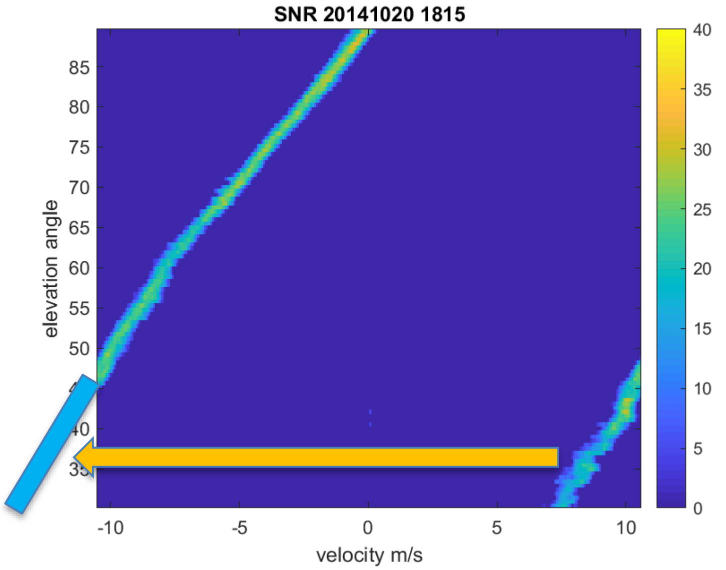




1. Doppler shift



2. Aliasing



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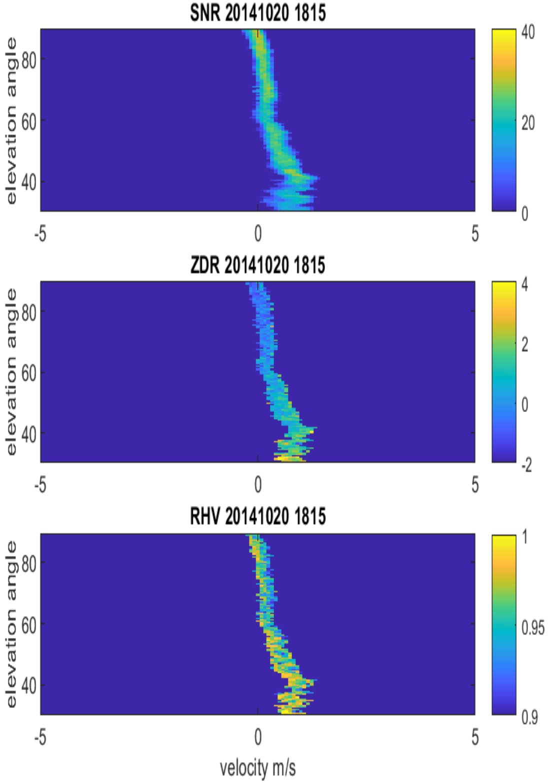
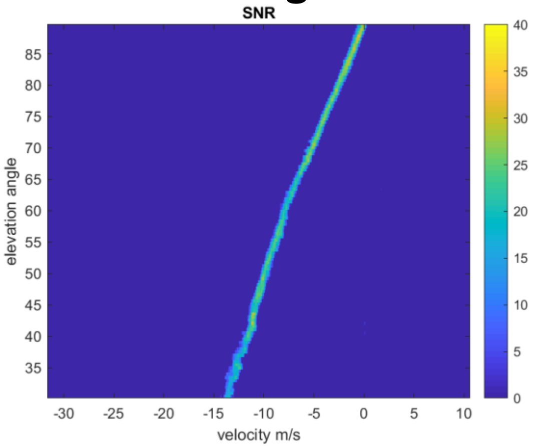
Case study: Correction for horizontal wind effects and Doppler folding

→ Application at all elevation angles of RHI scan at 3100 m height

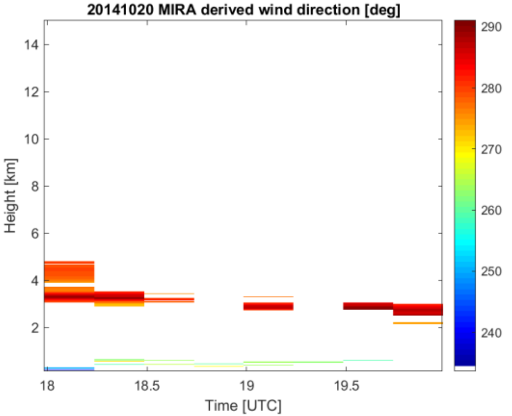
After wind correction

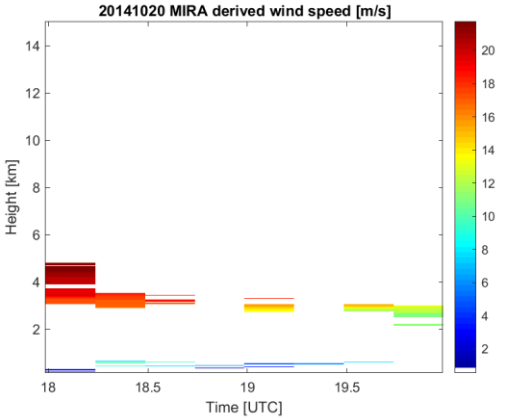


After folding correction



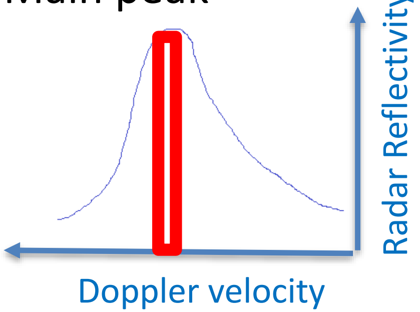
Wind profile



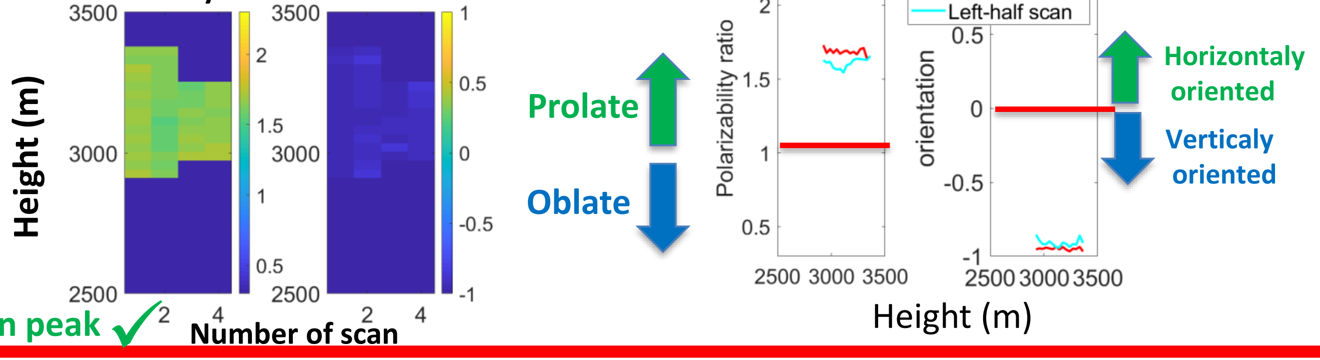


Retrieval result

Main peak

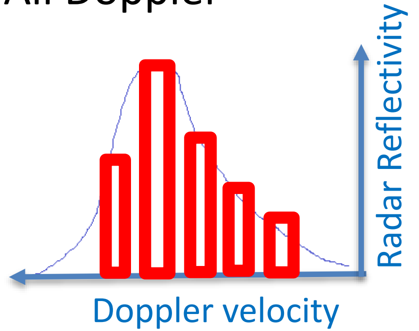


Based on 4 RHI scans

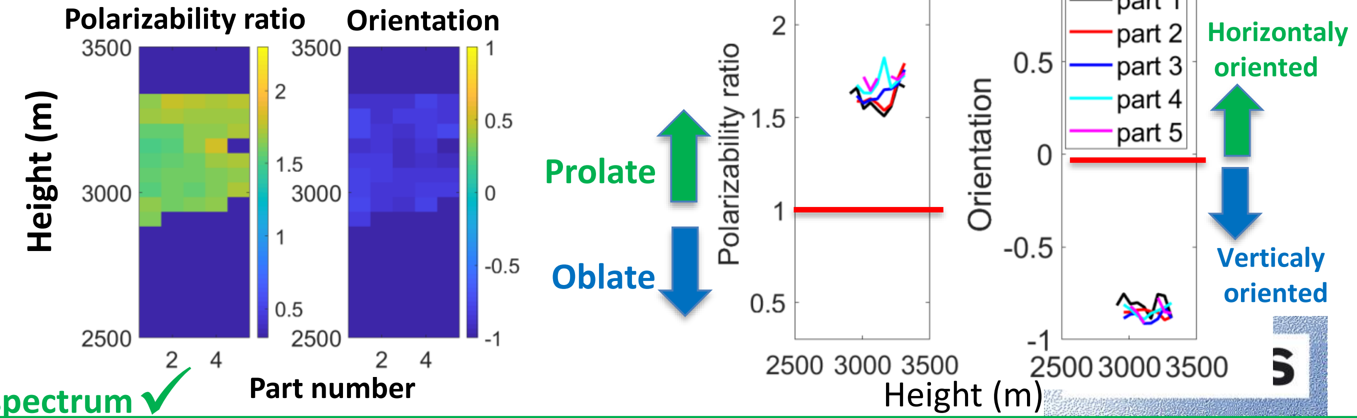


Myagkov's algorithm works on main peak ✓

All Doppler



Based on 5 spectral bins of 1 RHI scan

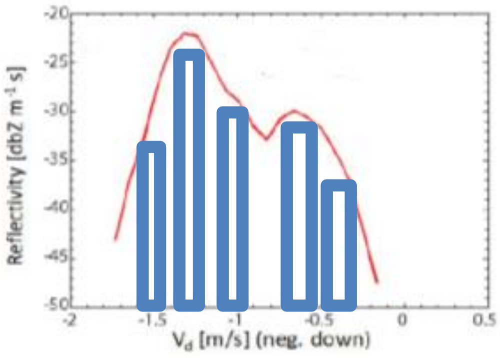


extended algorithm works on all spectrum ✓

Next Steps

Thanks for your attention!

1. **Apply the spectral shape retrieval to ACCEPT dataset**
   - Concentrate on multi-peak situations
2. **Identify case studies for joint investigations with AMPS spectral-bin model and polarimetric observations**



?

Is the spectrally resolved retrieval algorithm able to identify multiple, co-located shapes of ice particles?

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