IcePolCKa
Phase 2

# Augmenting the German weather radar network with vertically pointing cloud radars: implications of resolution and attenuation

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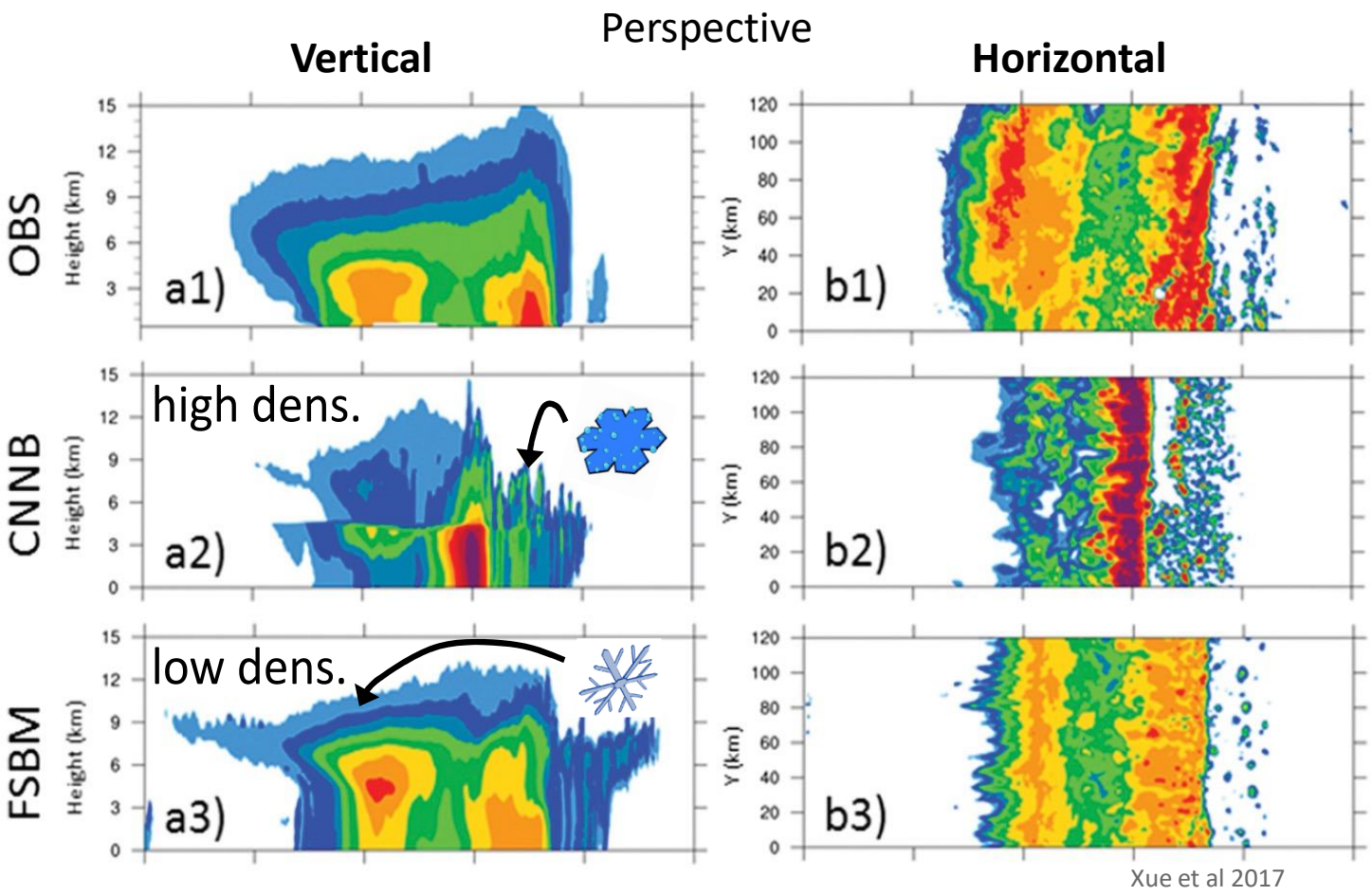
DLR

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

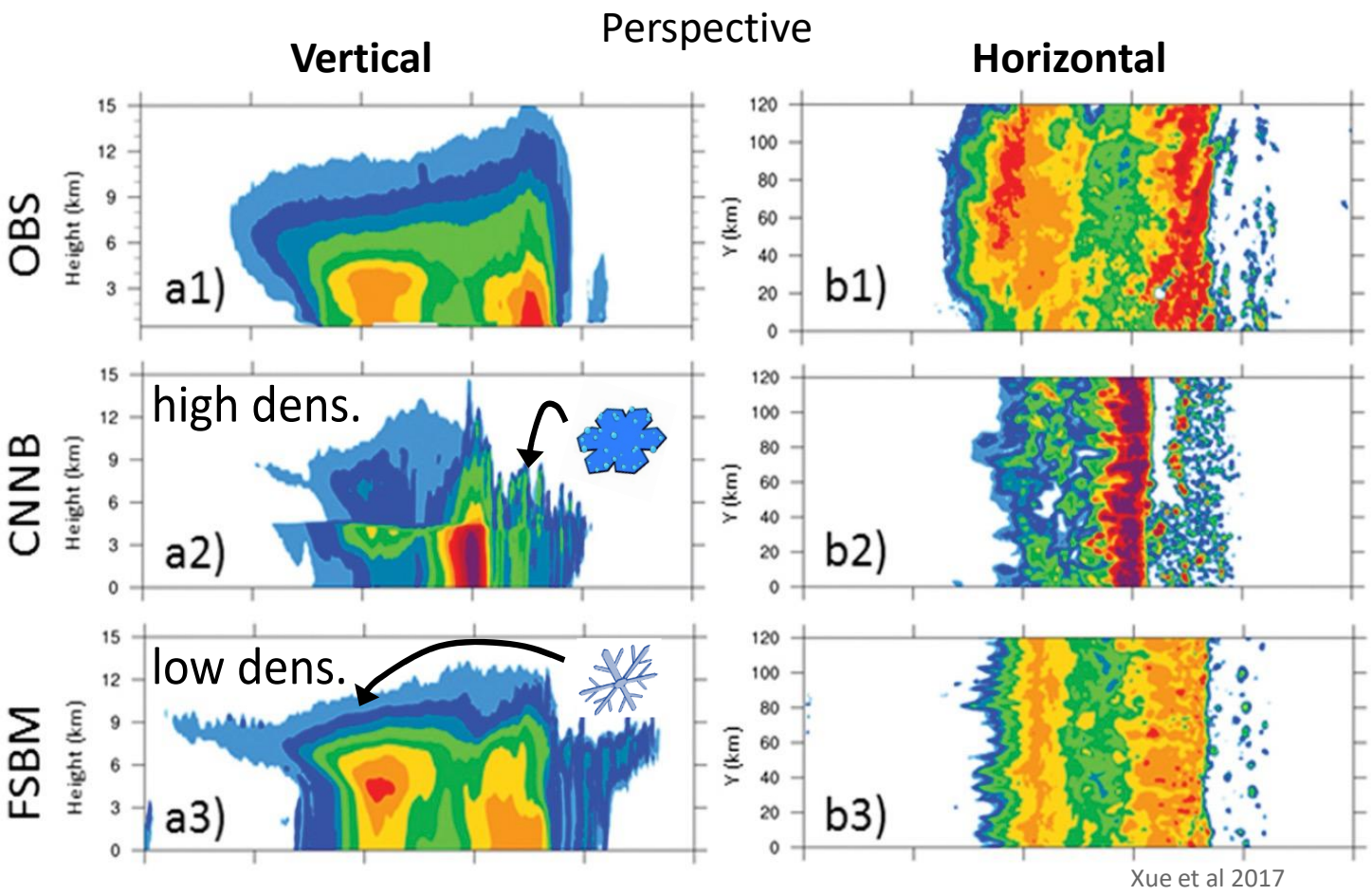
# Motivation




Xue et al 2017


S-Band NEXRAD measurements of squall line event measured in Morris, Oklahoma 20.05.2011

# Motivation




Xue et al 2017

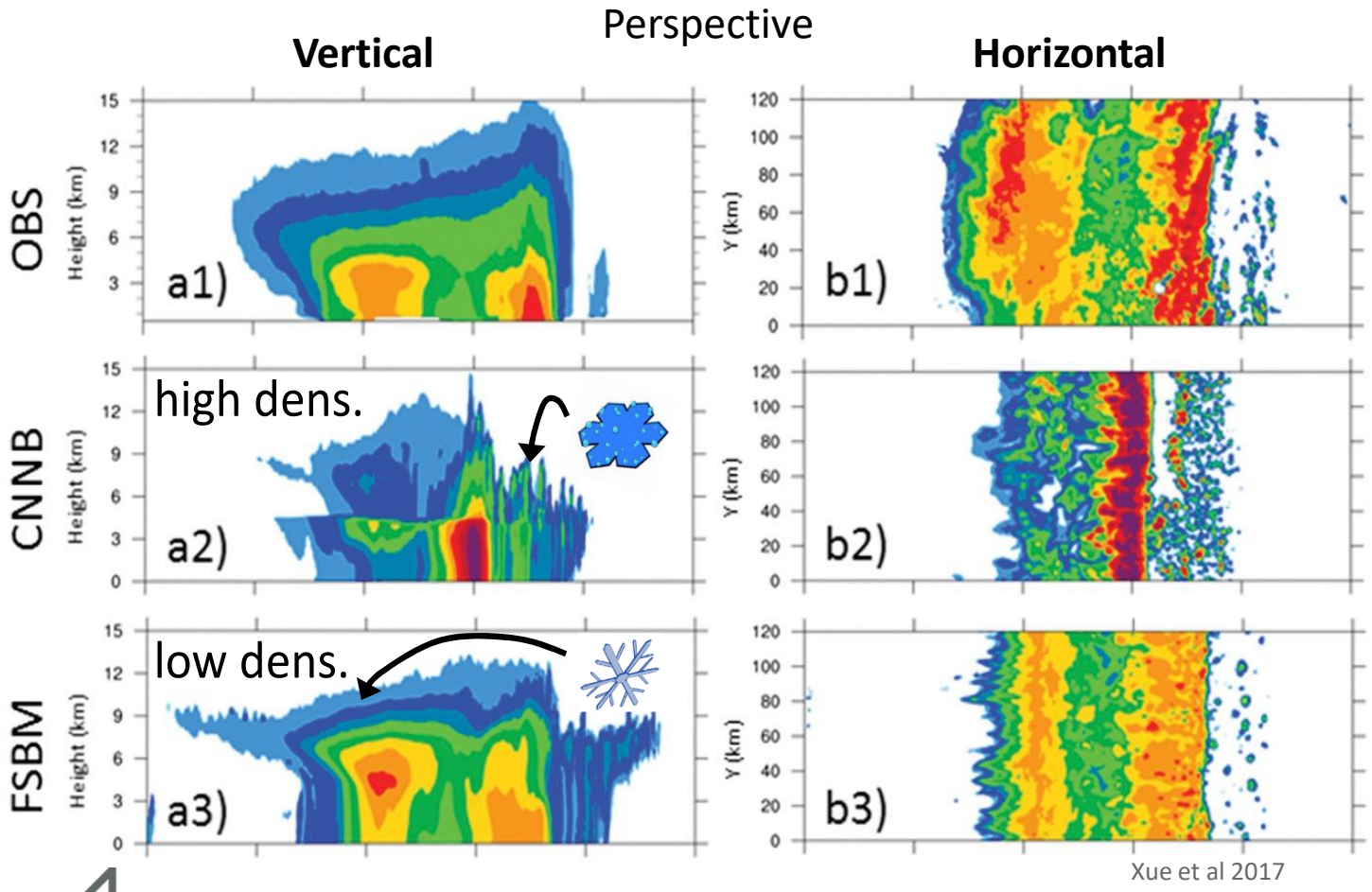
S-Band NEXRAD measurements of squall line event measured in Morris, Oklahoma 20.05.2011

→ **Ice particle shape** and density have a **large influence** on the **spatial partition** of convective and stratiform region

# Motivation

**Research Gap**

*What role do ice particle properties play in the partitioning in convective and stratiform regions?*




Xue et al 2017

**Scientific objective:**

1) Observe how **convective and stratiform regions** evolve over time
   → horizontal statistics (Obs. vs WRF)

2) Retrieve **ice particle shape and density** from DWR + ZDR and LDR + VEL
   → vertical statistics of cloud microphysics

3) Are **models right for of the right reasons?**
   → connect microphysical profiles with horizontal context

# Phase 1: Combination of two spatially separated radars

Photo by Martin Hagen

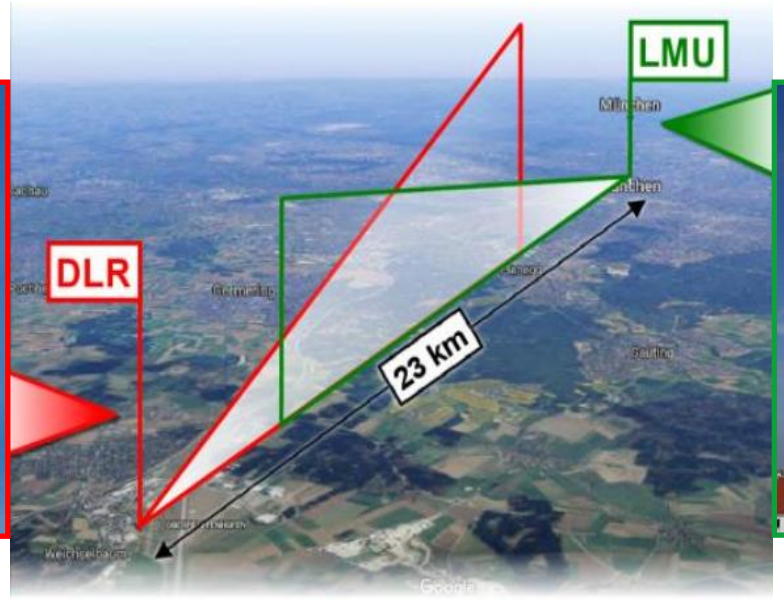



Photo by Florian Ewald

Photo by Bernhard Mayer

RHI scans of POLDIRAD (C-band) + RHI scans of MIRA-35 (Ka-band)

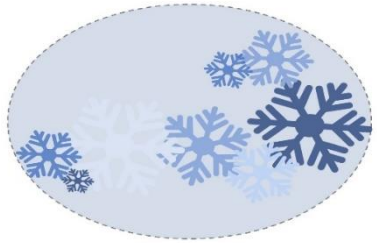
Stratiform snowfall precipitation in 2019



Tetoni et al. (2022)

# Phase 1: Retrieval development ZDR + DWR (PhD Eleni Tetoni)

Soft spheroid model



Scattering simulation look-up tables in PyTMatrix
Leinonen (2014)

Mass-Size-Relationships

*Brown and Francis (1995)*

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

*Yang et al. (2000)*

$$m(D_{max}) = \frac{\pi \rho_w D_{eq}^3}{6} = \frac{\pi \rho_w}{6} e^{\sum_{n=0}^{4} b_n (\ln(D_{max}))^{n^3}}$$

Varying aspect ratio (AR), median mass diameter (Dm) and ice water content (IWC)

**Retrieval**
Ze, **DWR, ZDR**-> IWC, Dm, AR

Tetoni et al. (2022)

# Phase 2: Outlook

| | Phase 1 | Phase 2 |
|---|---|---|
| **Data** | RHI data of C-band and Ka-band radars pointing to each other | • Simultaneous measurement of ZDR, MDV, LDR<br>• Dedicated or operational radars ? |
| **Simulation** | T-matrix with soft spheroids | |
| **Retrieval** | Ze, DWR, ZDR-> IWC, Dm, AR | |

# Phase 2: Outlook

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# Phase 2: Outlook

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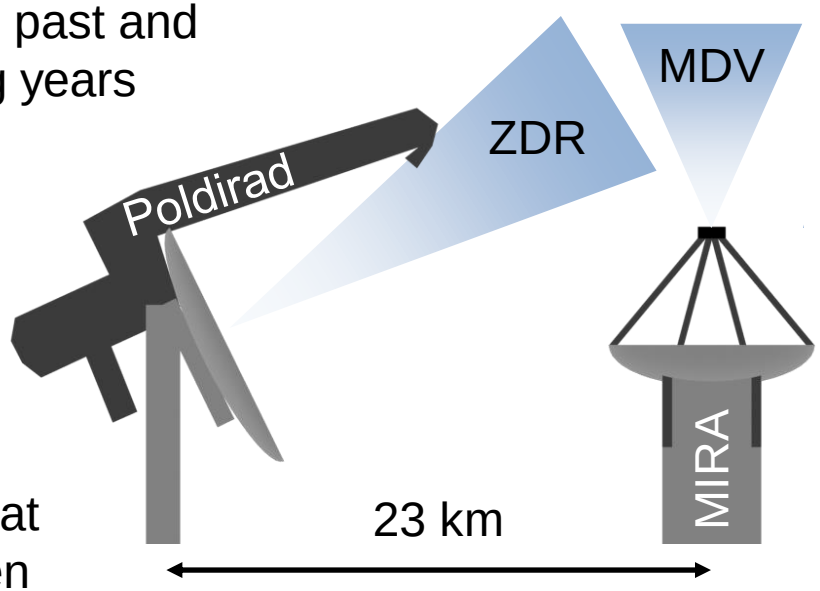
| **Retrieval** | Ze, DWR, ZDR-> IWC, Dm, AR | Ze, DWR, ZDR, **LDR, MDV**<br>→ IWC, Dm, AR, **shape, m(D)** |

# Phase 2: Combination of two spatially separated radars
# Research question 1: dedicated / operational ?

Data from past and coming years




POLDIRAD (C-band) at DLR Oberpfaffenhofen doing RHI scans

Mira-35 (Ka-band) at LMU doing profile scans

# Phase 2: Combination of two spatially separated radars
# Research question 1: dedicated / operational ?

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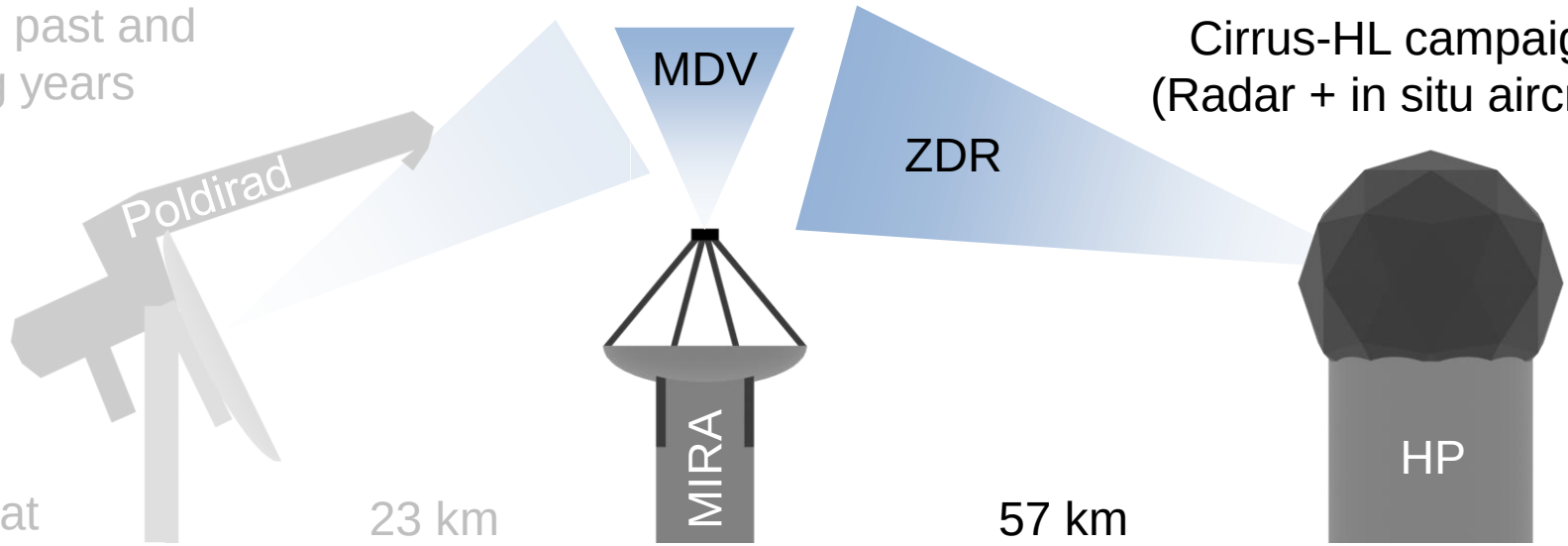


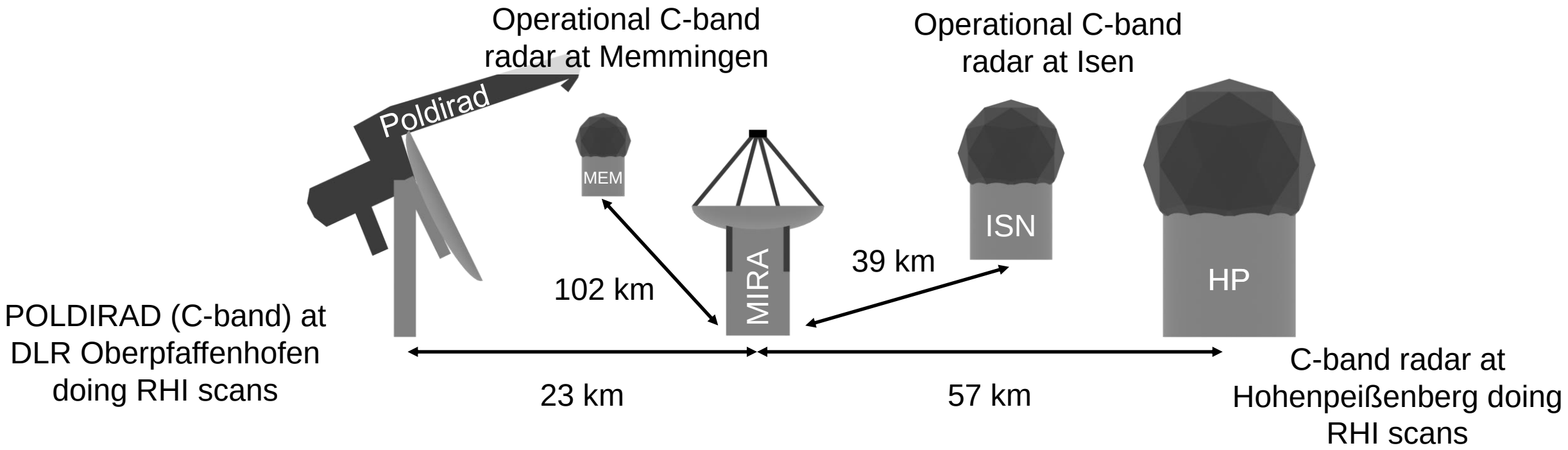

Cirrus-HL campaign
(Radar + in situ aircraft)

POLDIRAD (C-band) at DLR Oberpfaffenhofen doing RHI scans

Mira-35 (Ka-band) at LMU doing profile scans

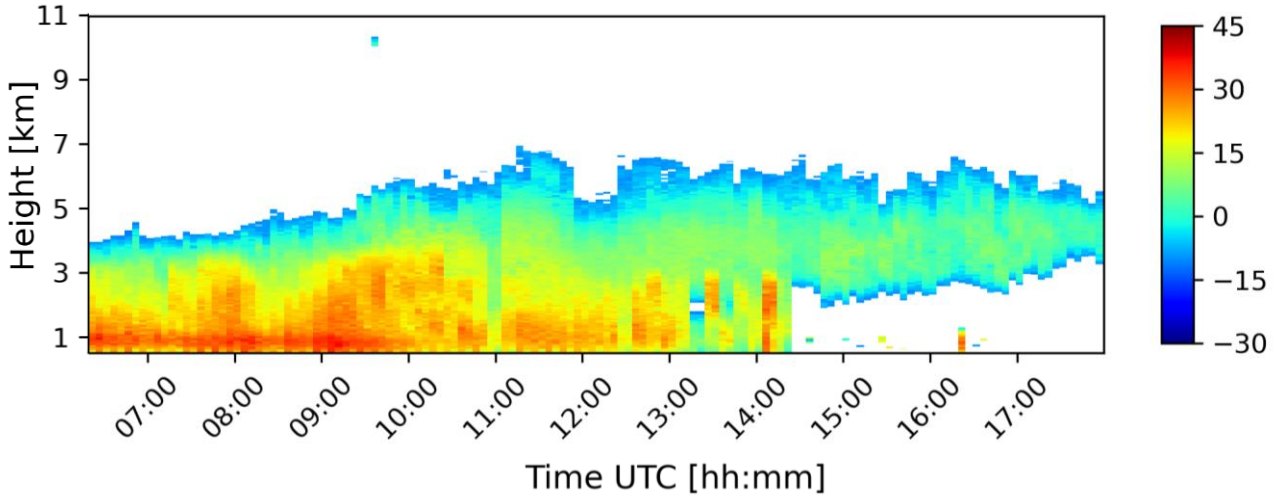
C-band radar at Hohenpeißenberg doing RHI scans

# Phase 2: Combination of two spatially separated radars
# Research question 1: dedicated / operational ?



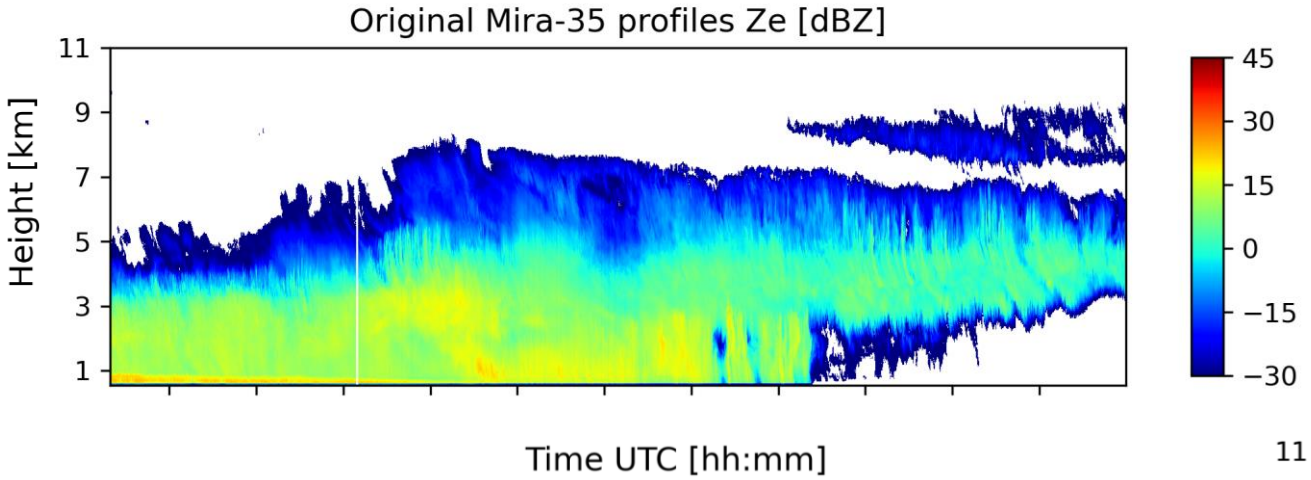
# Phase 2: Case study on 01.02.2018

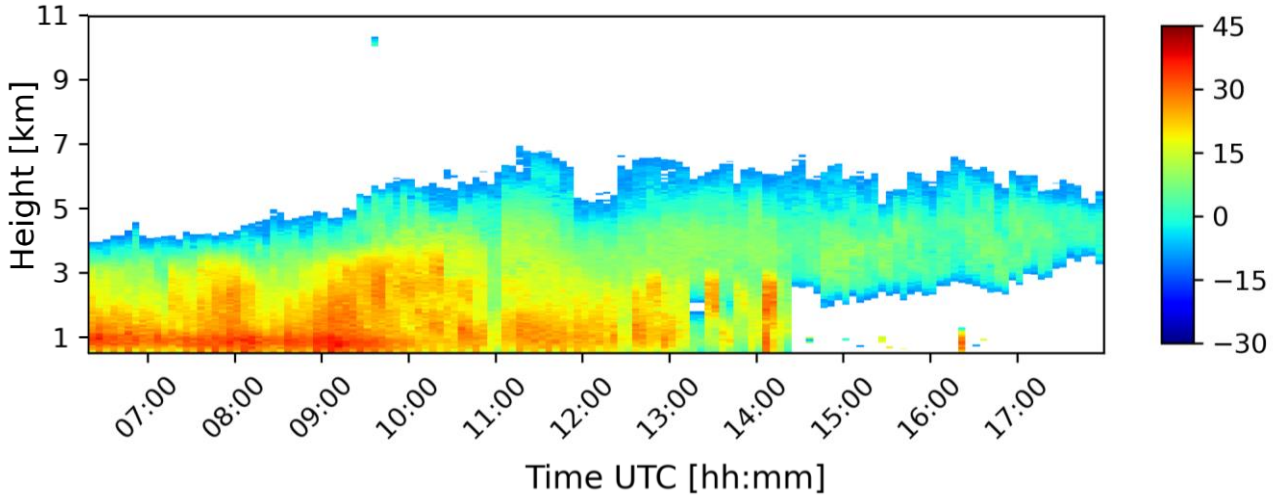
RHI, 23km



# Phase 2: Case study on 01.02.2018


Profiles + RHI, 23km



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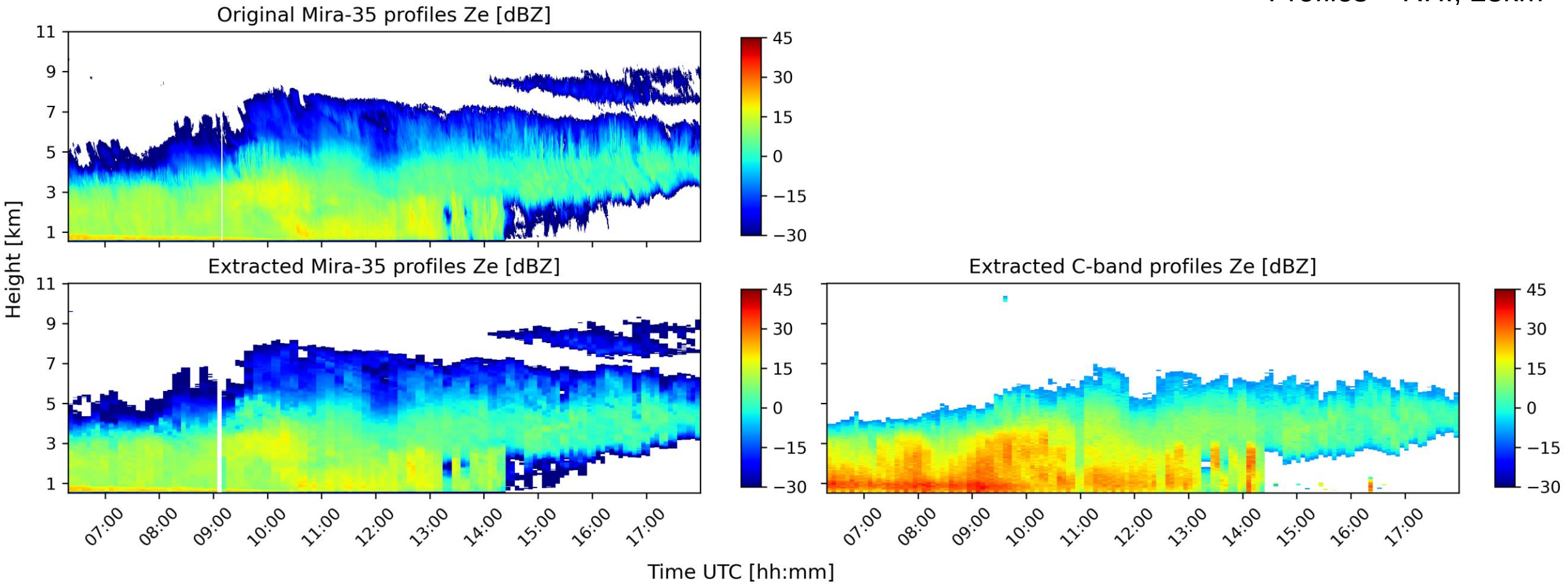
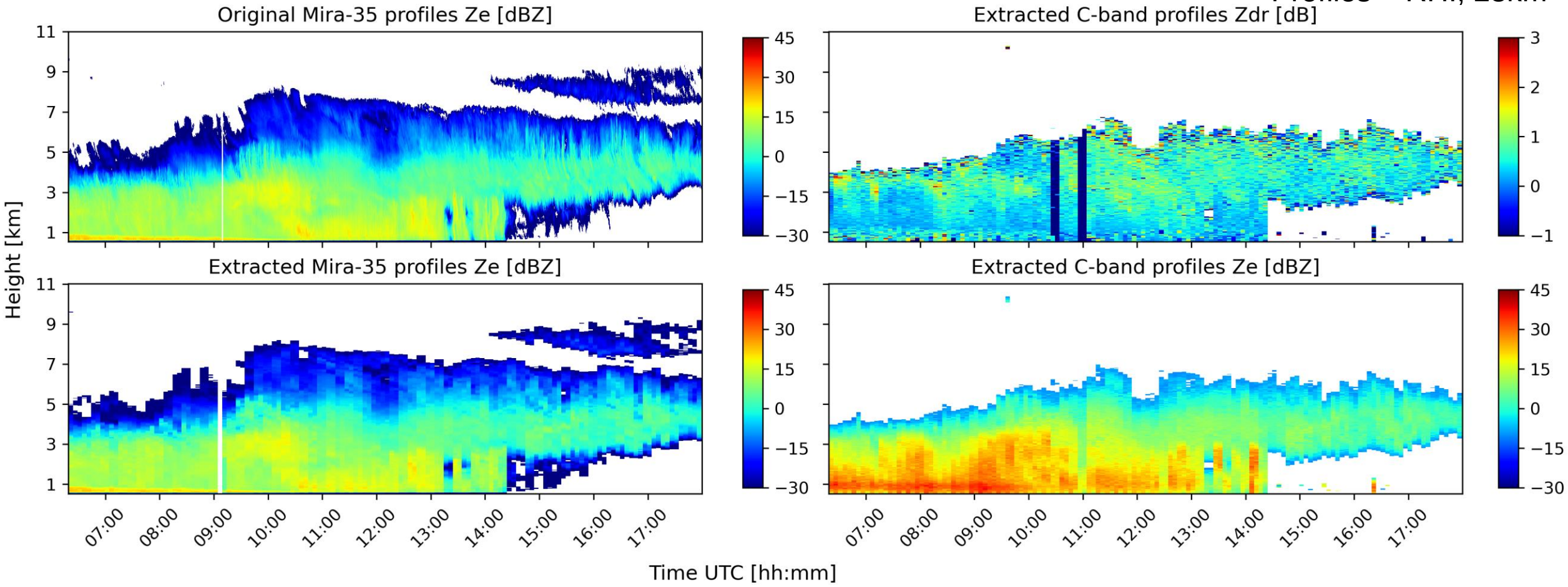
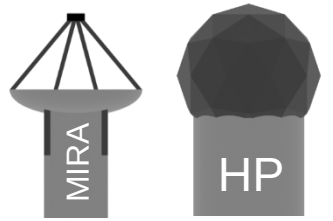


# Phase 2: Case study on 01.02.2018

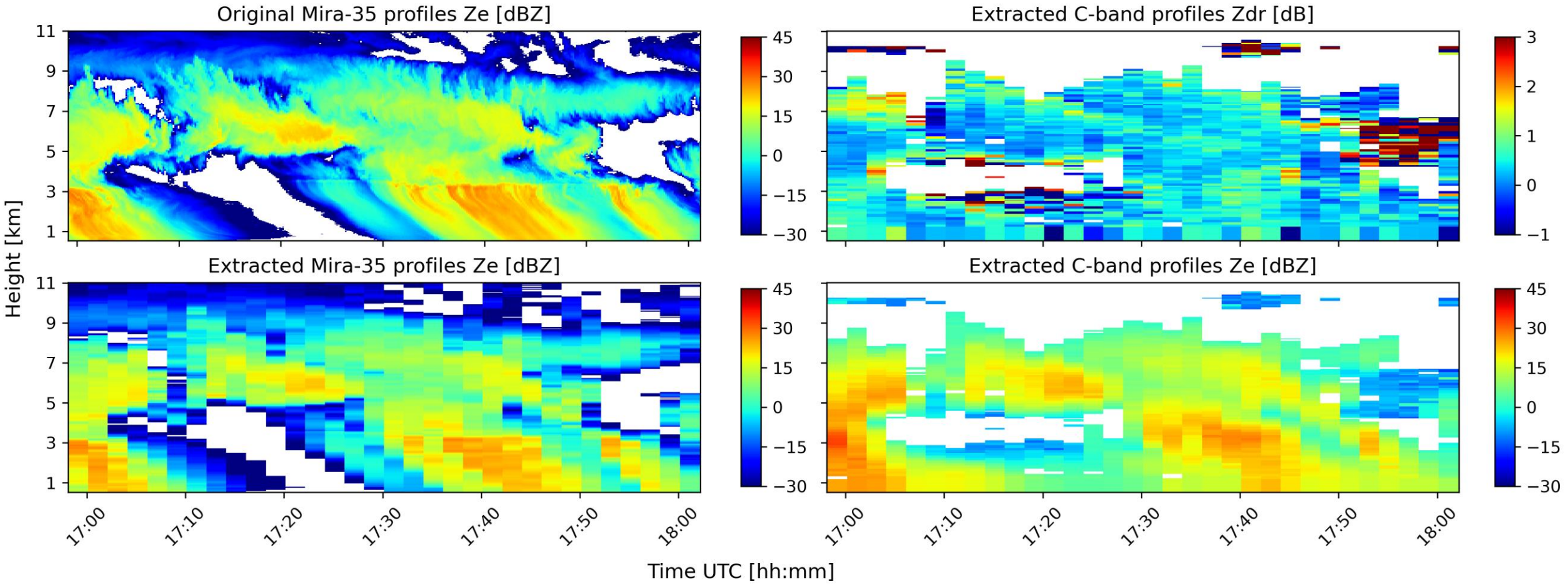

Profiles + RHI, 23km



# Phase 2: Case study Cirrus-HL on 08.07.2021

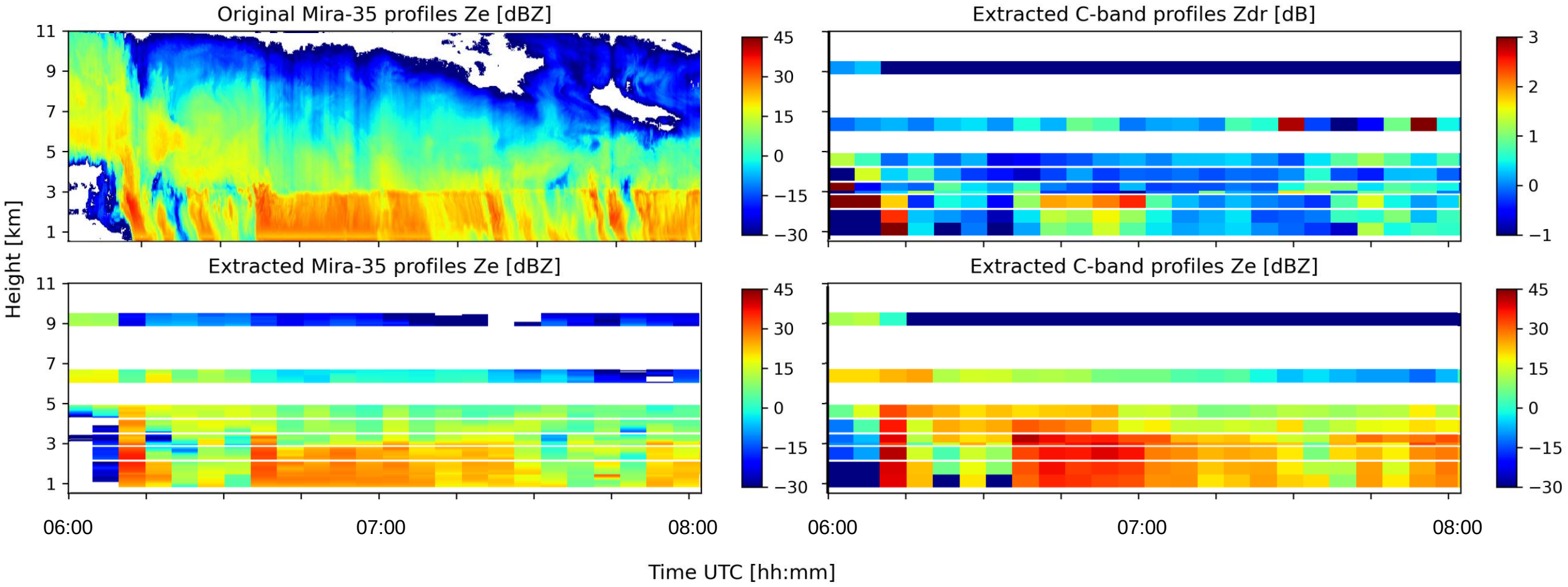



Profiles + RHI, 57km

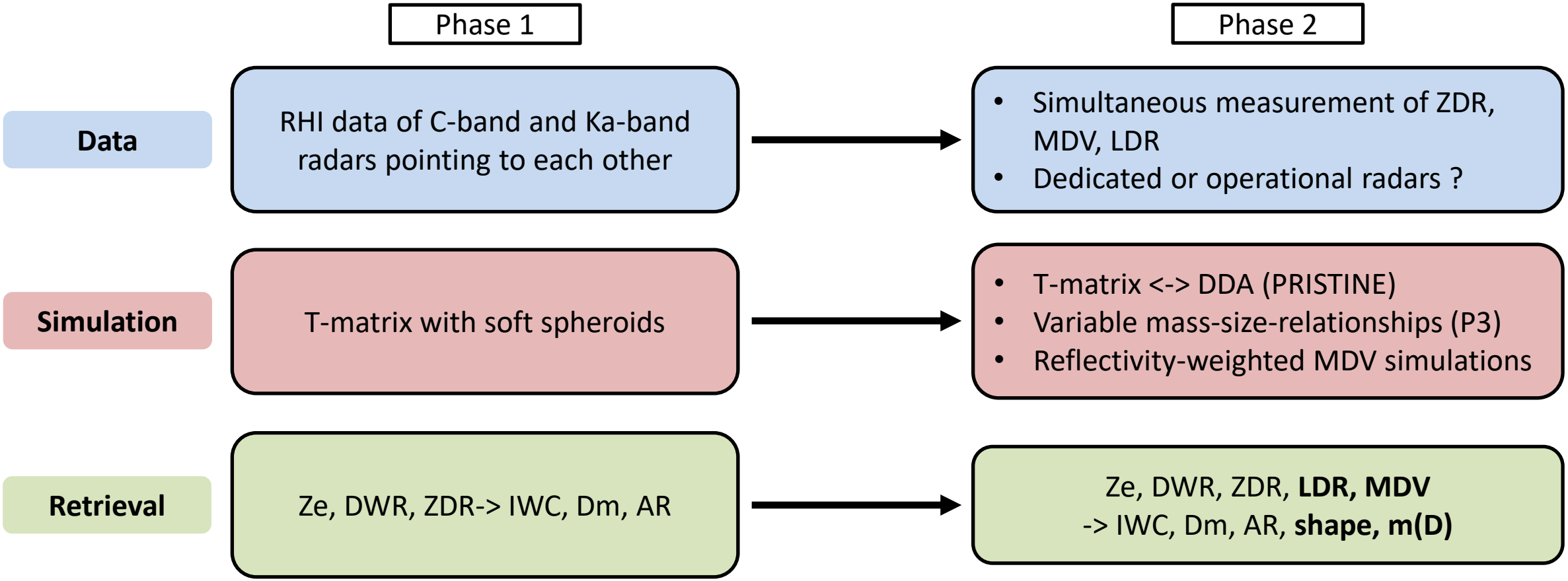


# Phase 2: DWD data from 07.07.2019

Profiles + PPI, 39km



# Phase 2: Outlook



# 1st Year of the PhD so far

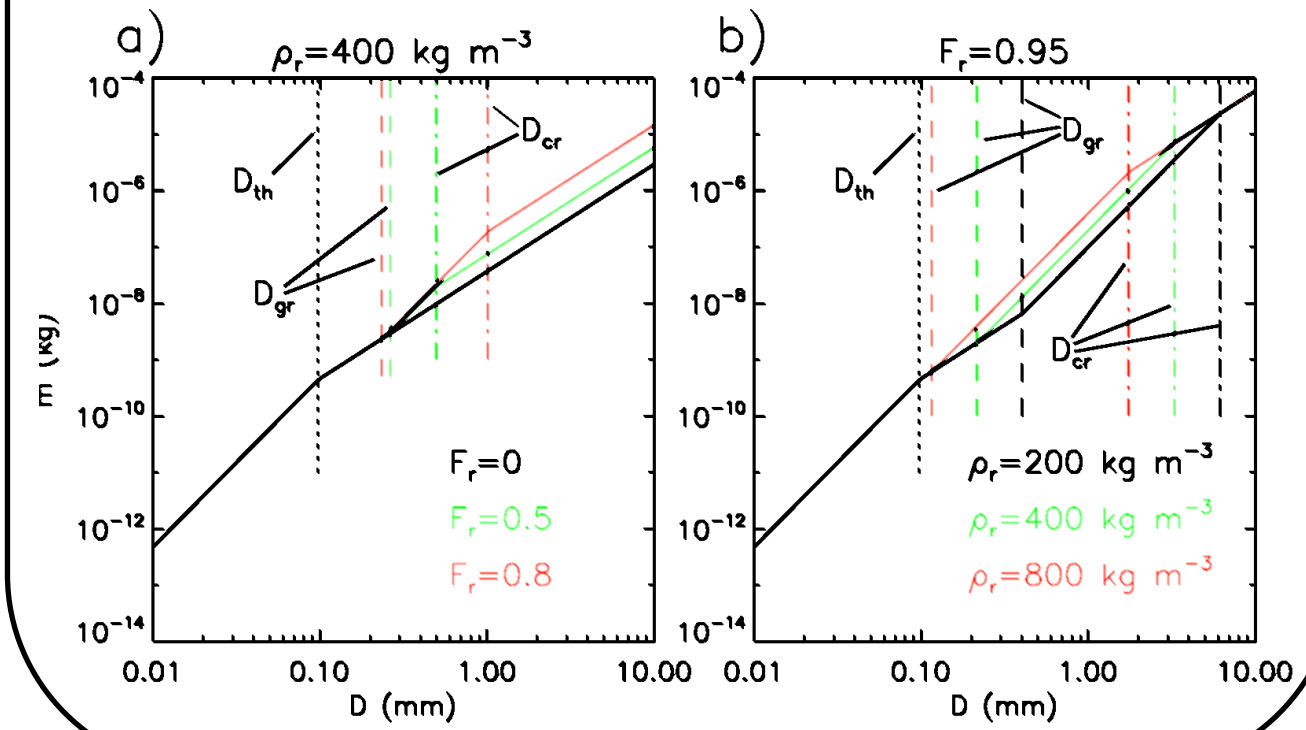
**T-Matrix Simulations**

- Changed from Eleni´s single/double model approach to the p3 model
- Added MDV as simulation output

Mass-Size-Relationship $m = \alpha D^{\beta}$

Coefficients change depending on model

P3 model alters the mass-size-relationship depending on *D and* introduces riming fraction *FR*




Morrison and Mildbrandt (2015)

# 1st Year of the PhD so far

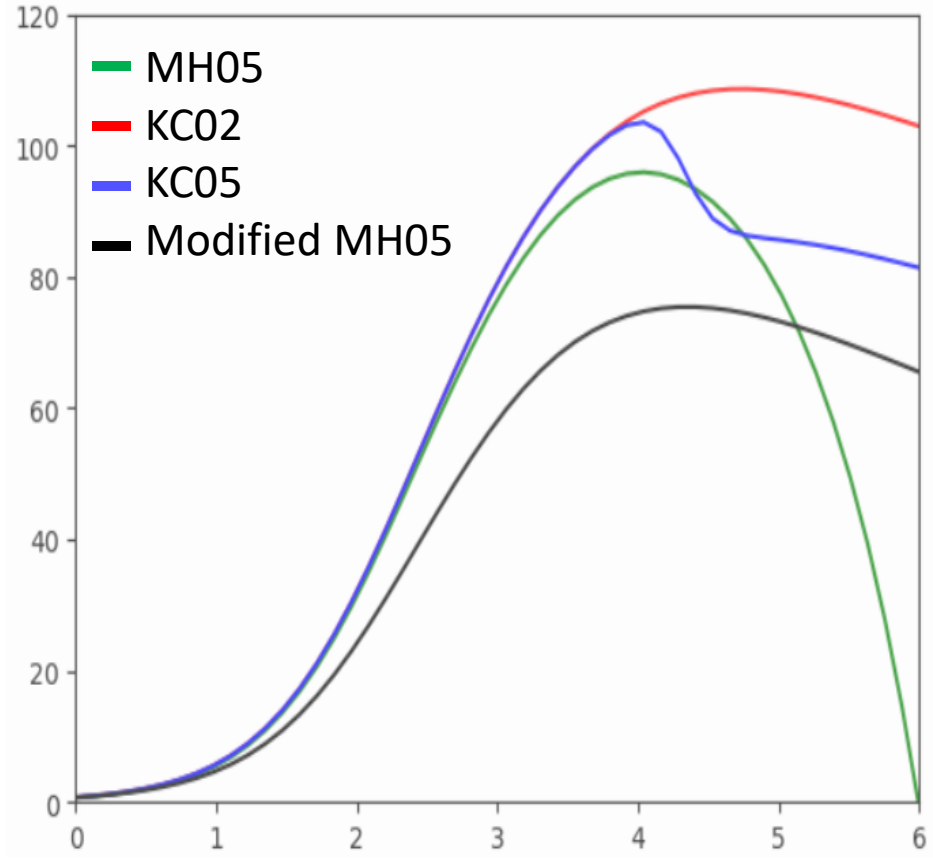
**T-Matrix Simulations**

- Changed from Eleni´s single/double model approach to the p3 model
- Added MDV as simulation output

Area-Size-Relationship

$$A = \gamma D^{\sigma}$$

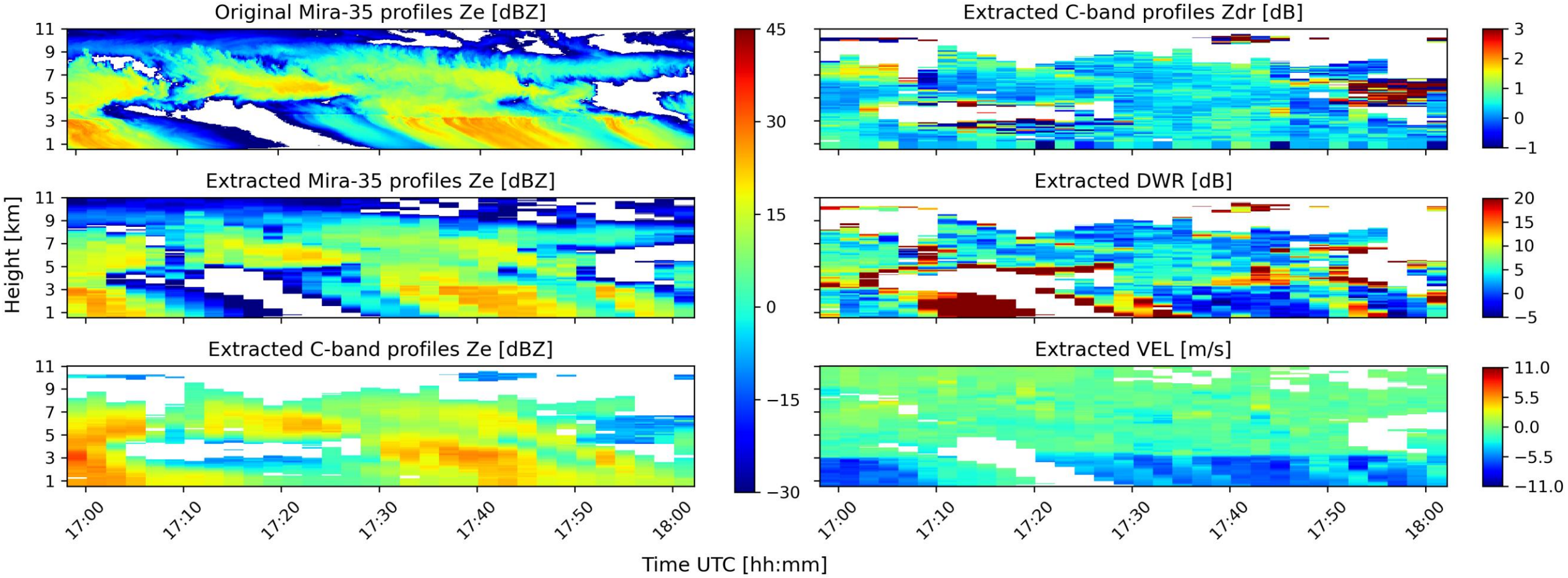
Coefficients change depending on model



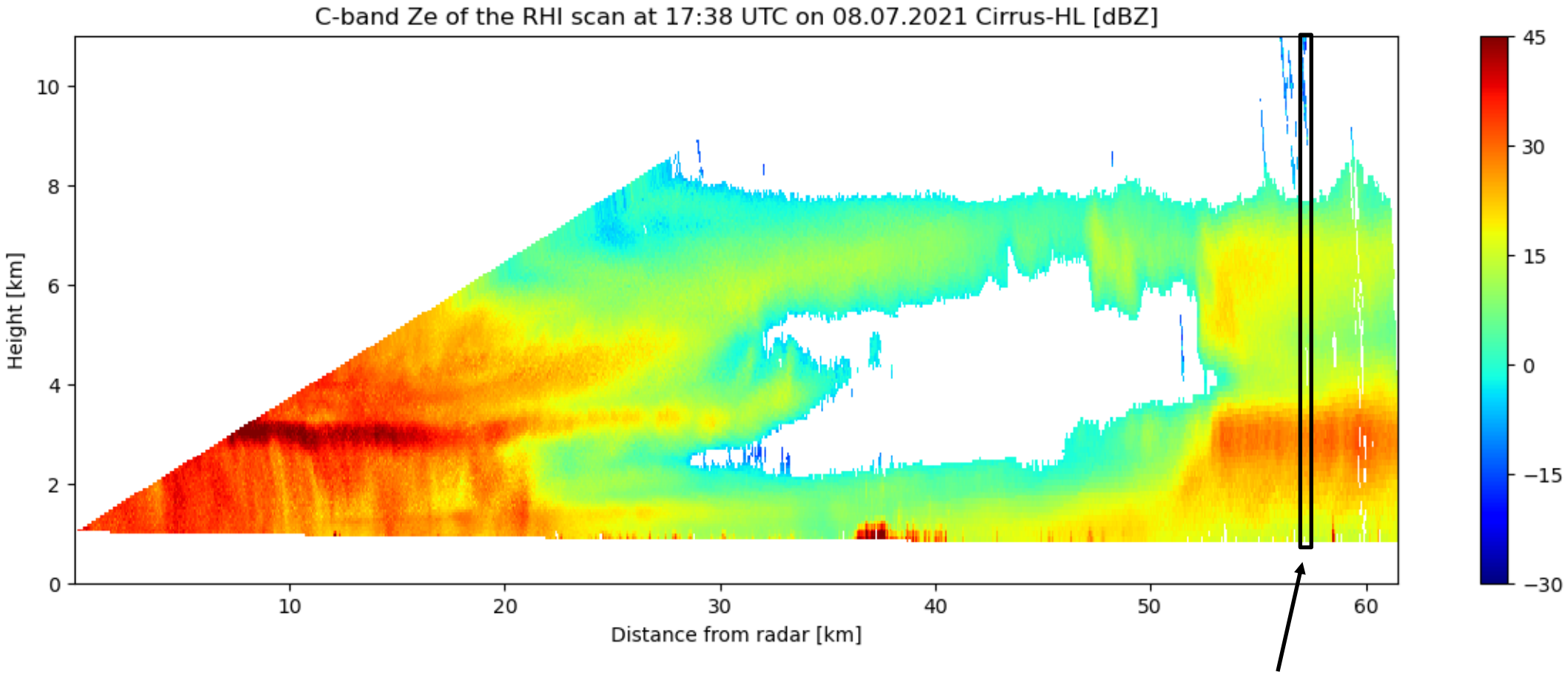


Khvorostyanov and Curry (2002)
Khvorostyanov and Curry (2005)
Mitchell and Heymsfield (2005)
Heymsfield and Westbrook (2010)


# Backup


Original Mira-35 profiles Ze [dBZ]
Extracted Mira-35 profiles Ze [dBZ]
Extracted C-band profiles Ze [dBZ]
Extracted C-band profiles Zdr [dB]
Extracted DWR [dB]
Extracted VEL [m/s]
Height [km]
Time UTC [hh:mm]
11
9
7
5
3
1
45
30
15
0
−15
−30
3
2
1
0
−1
20
15
10
5
0
−5
11.0
5.5
0.0
−5.5
−11.0
17:00
17:10
17:20
17:30
17:40
17:50
18:00

# Phase 2: Combination of two (or more) spatially separated radars



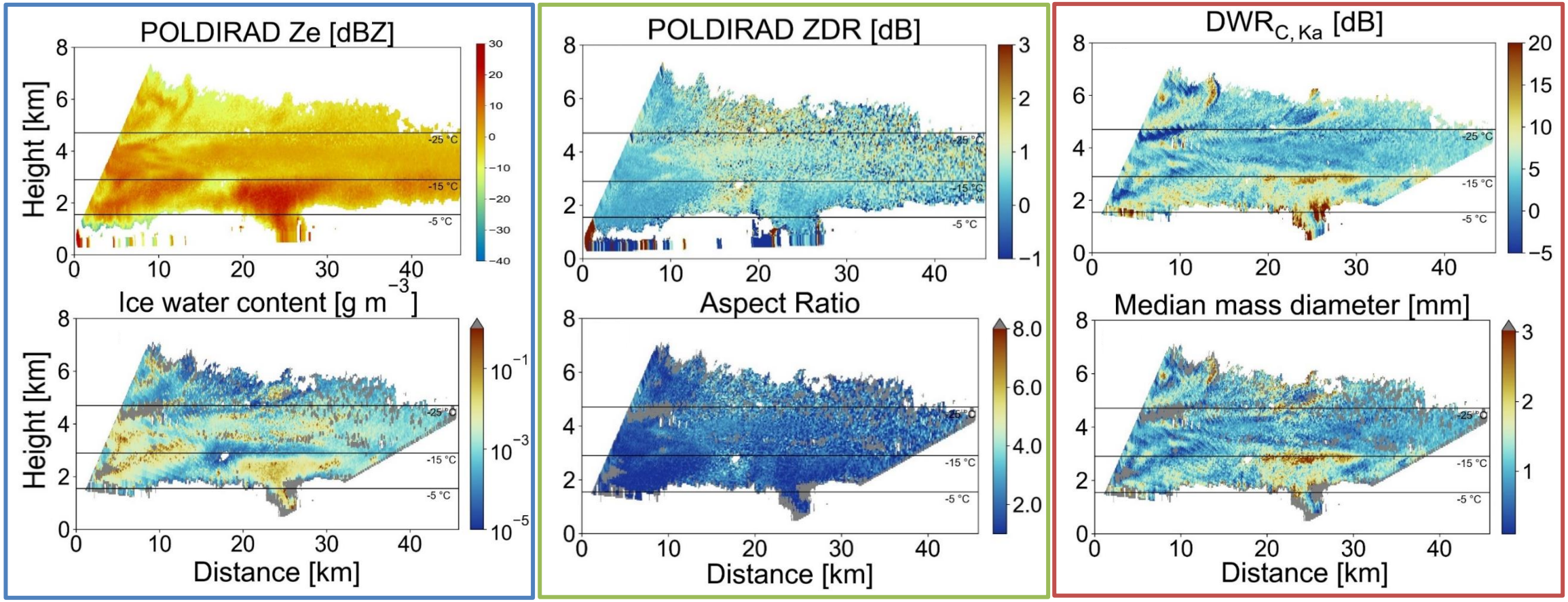

Extract vertical profile of C-band RHI scan at position of Mira-35 for all available RHI scans

# Phase 1 results: Ice retrieval case study of 30.01.2019 at 10:08 UTC

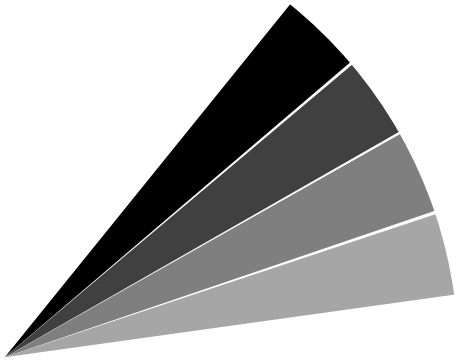
mass | shape | size

radar measurements

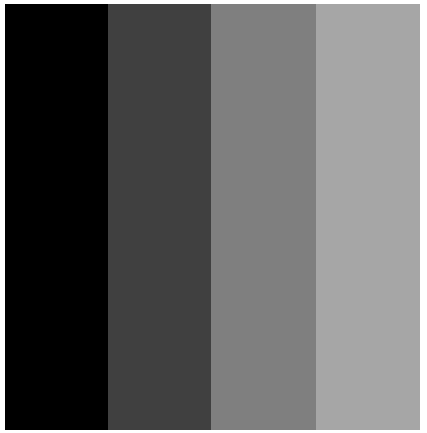
Yang m(Dmax), oblate ice spheroids



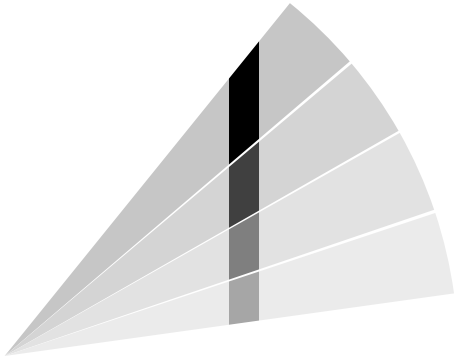
# Timely matching Mira data pixels to RHI/PPI scan times

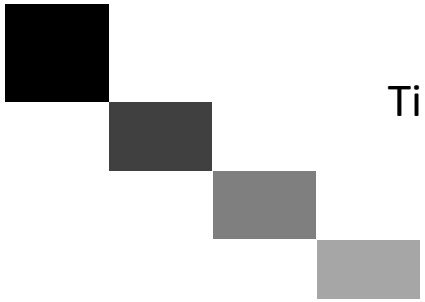


Measurement times RHI/
RHI extracted from PPI
T = 0s
T = +20s
T = +40s
T = +60s



Measurement time of Mira Profile (wrong average time of 20s for better understandability)
T = 0s
T = +20s
T = +40s
T = +60s

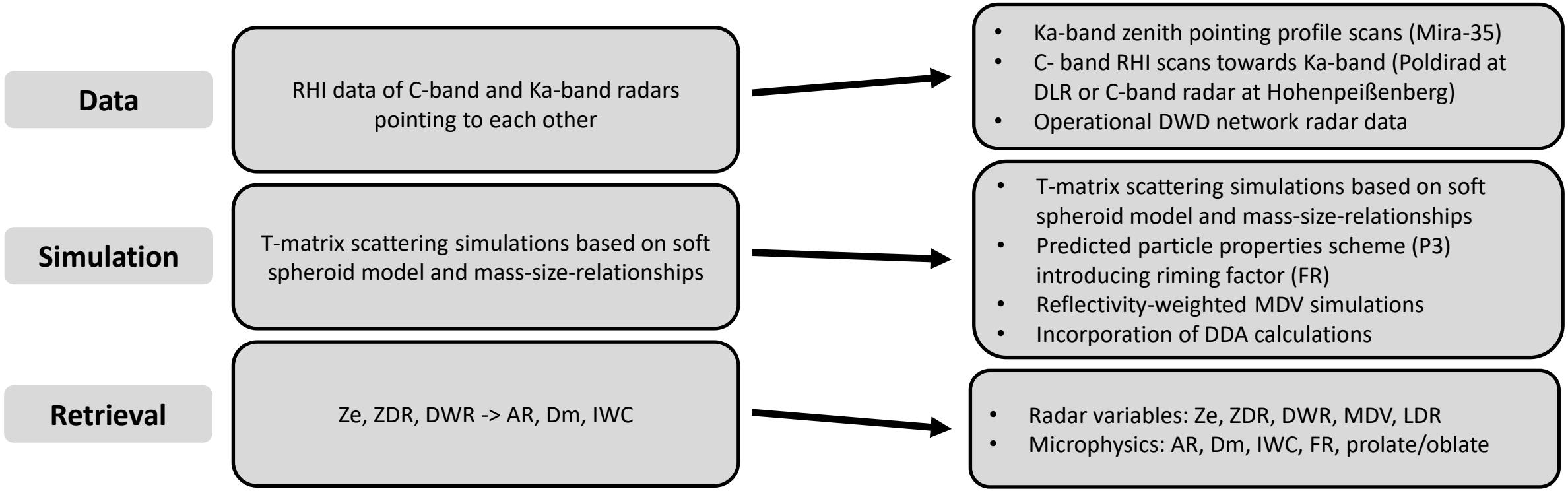




Timely matched profile

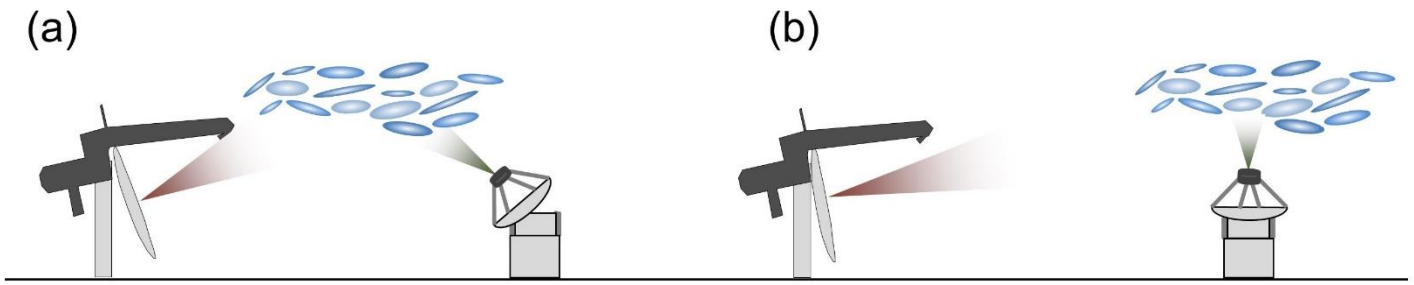
Extracted quasi-vertical profiles over Mira

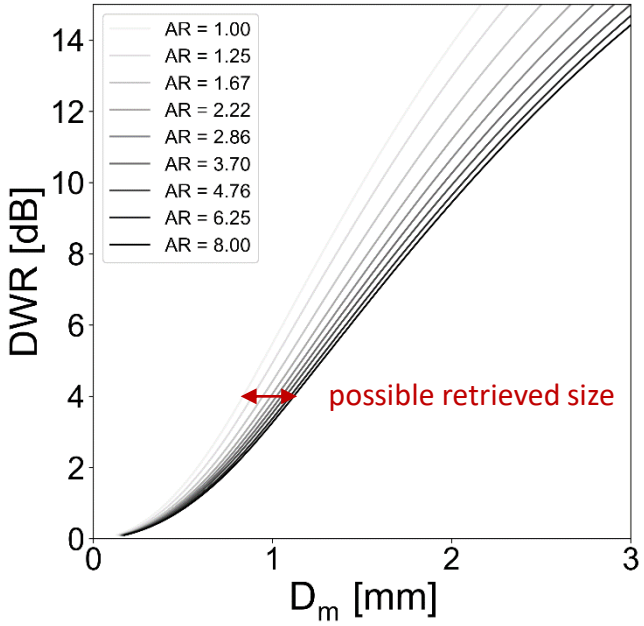
# Phase 2: Outlook

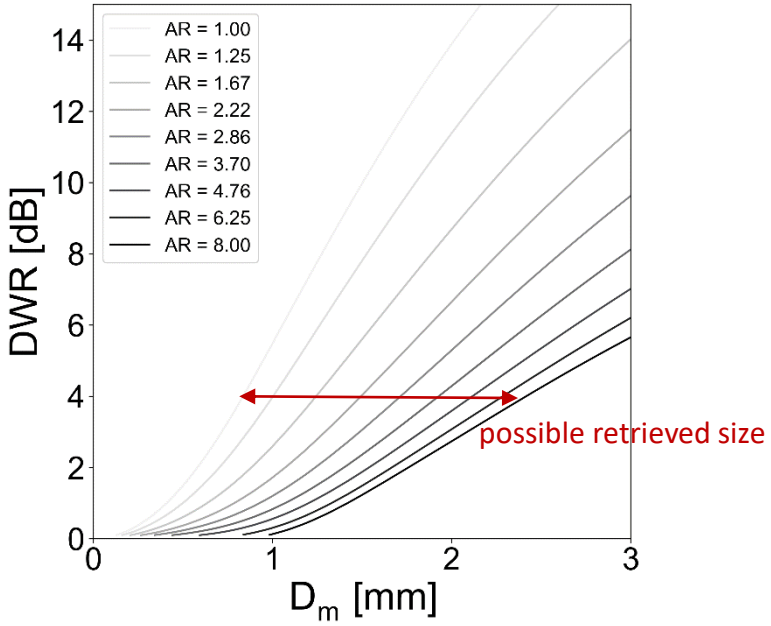


# RQ3: Sensitivity studies

## Contribution of polarimetry



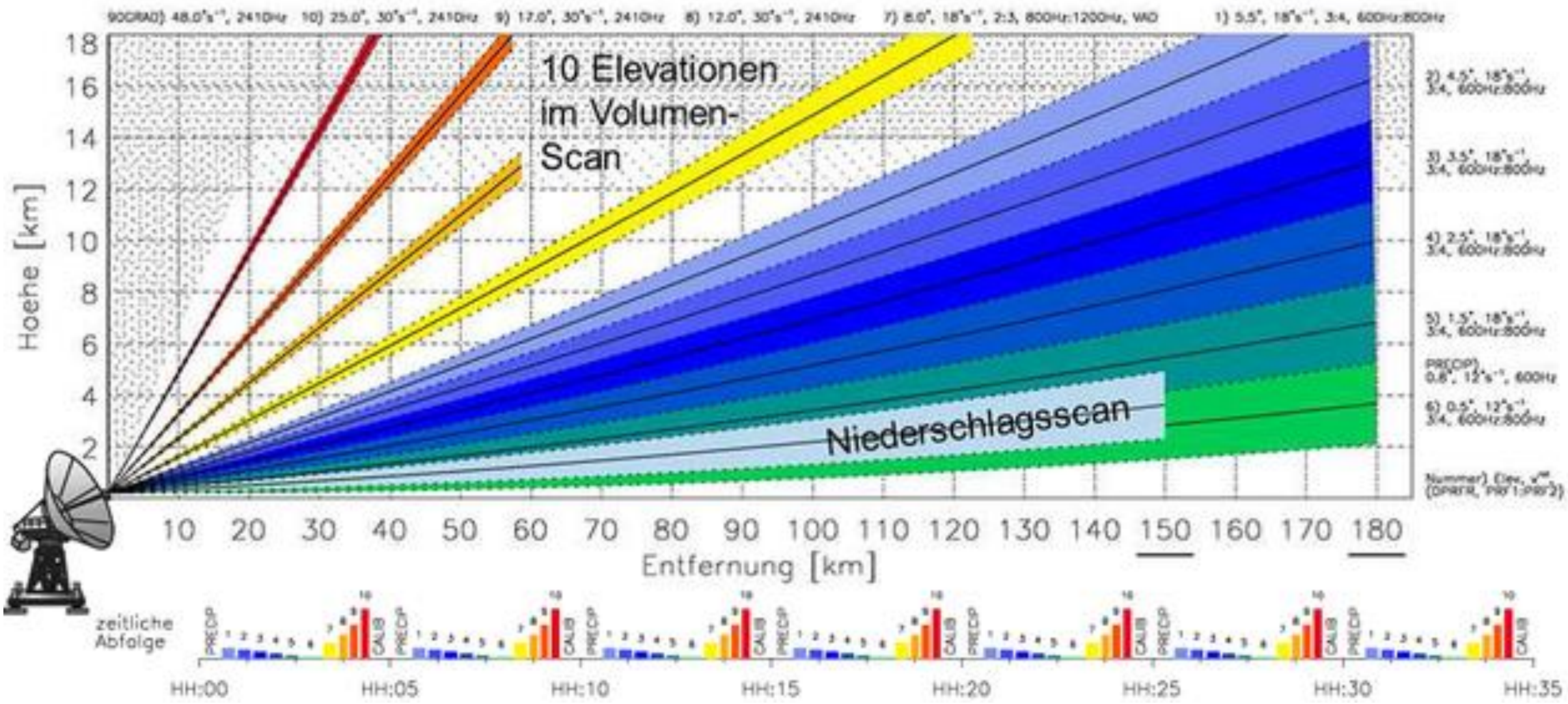




Above MIRA-35:

- the ambiguity for the different AR values is larger
- ZDR constrains the shape
- ZDR helps in the size retrieval

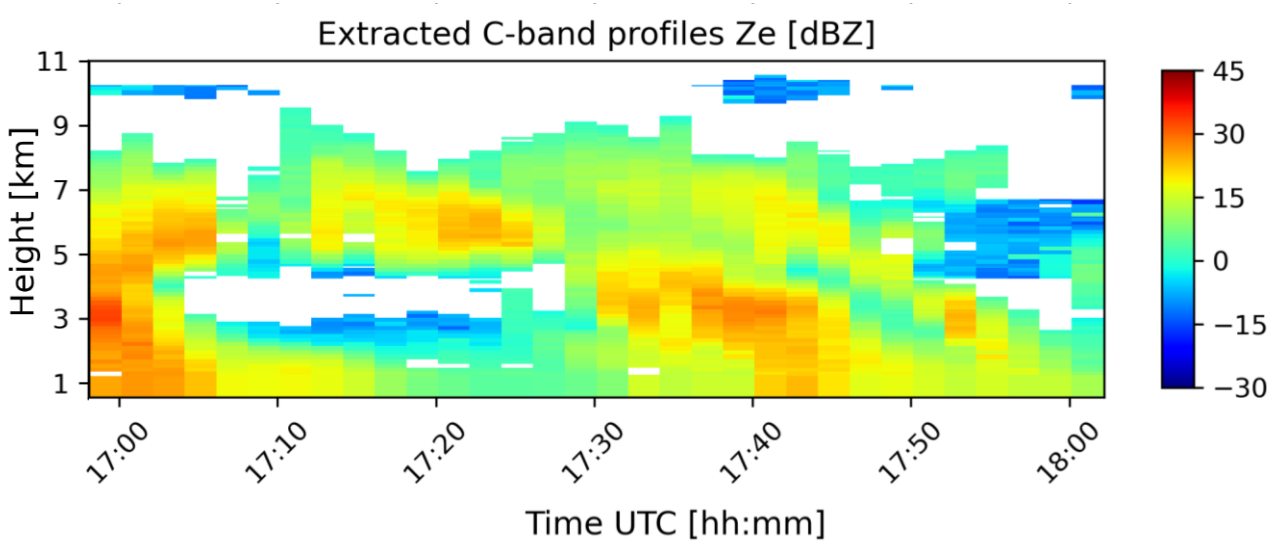
Tetoni et al. (2022), AMT


10 Elevationen
im Volumen-
Scan
Niederschlagsscan
Hoehe [km]
Entfernung [km]
zeitliche
Abfolge
HH:00
HH:05
HH:10
HH:15
HH:20
HH:25
HH:30
HH:35

# Phase 2: Case study Cirrus-HL on 08.07.2021

+POLDI vorher, Datenverfügbarkeit ansprechen

HP



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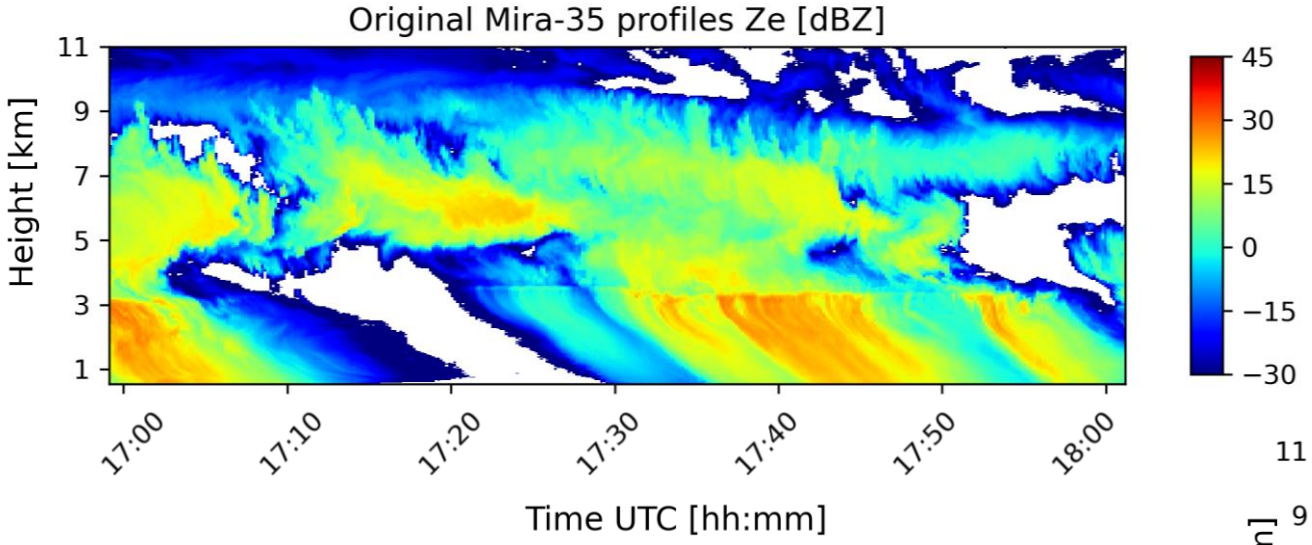


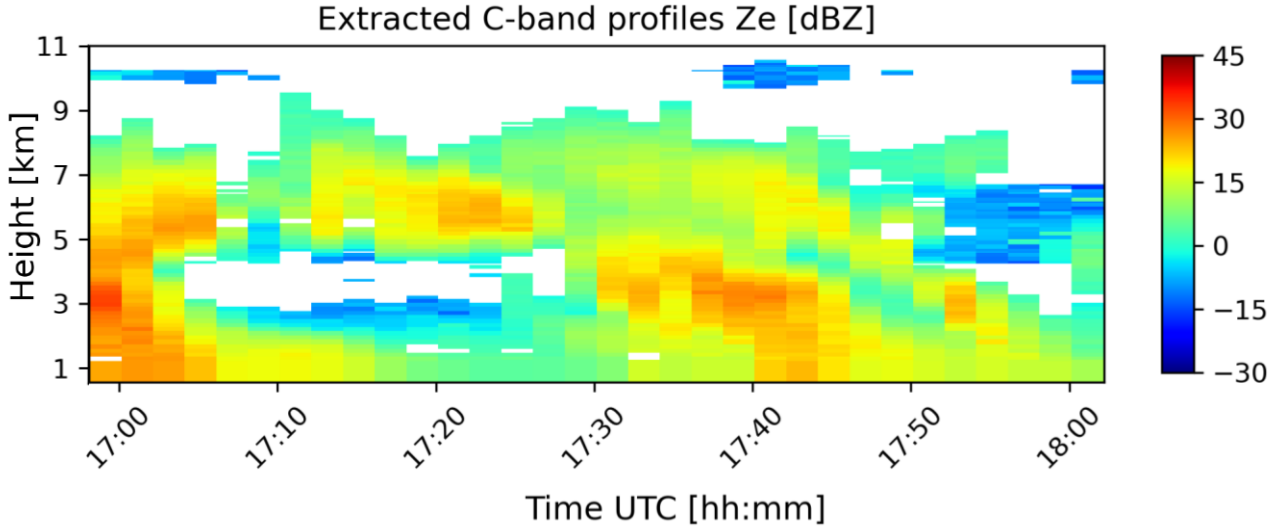

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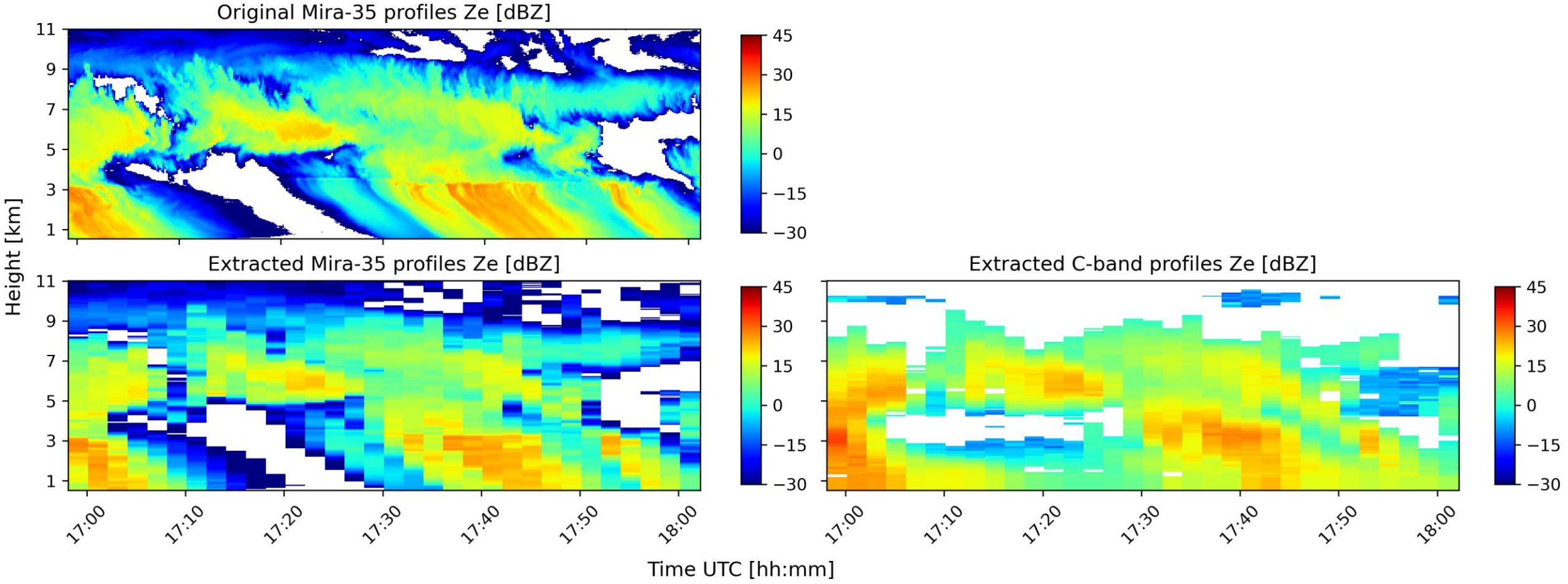
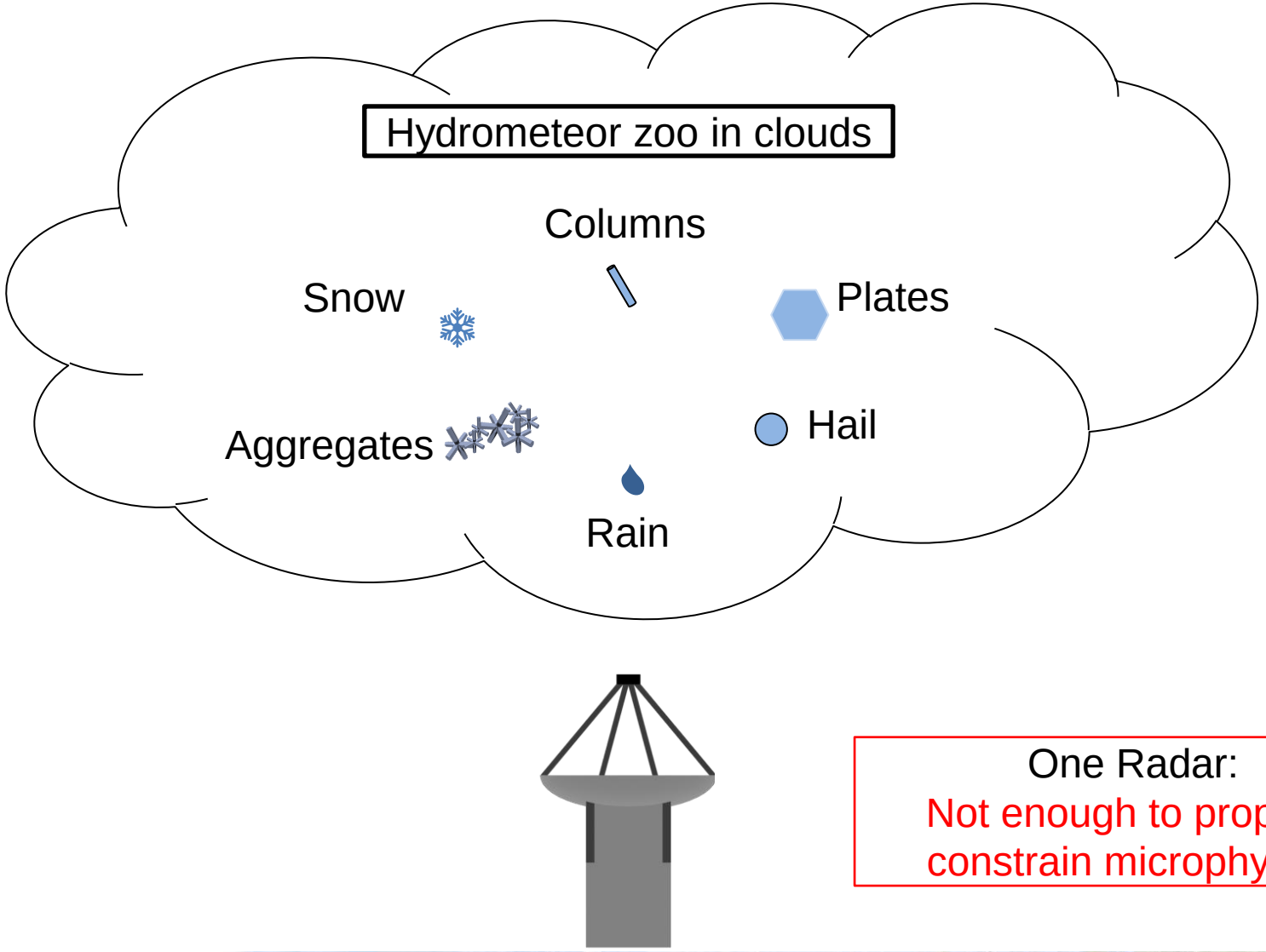
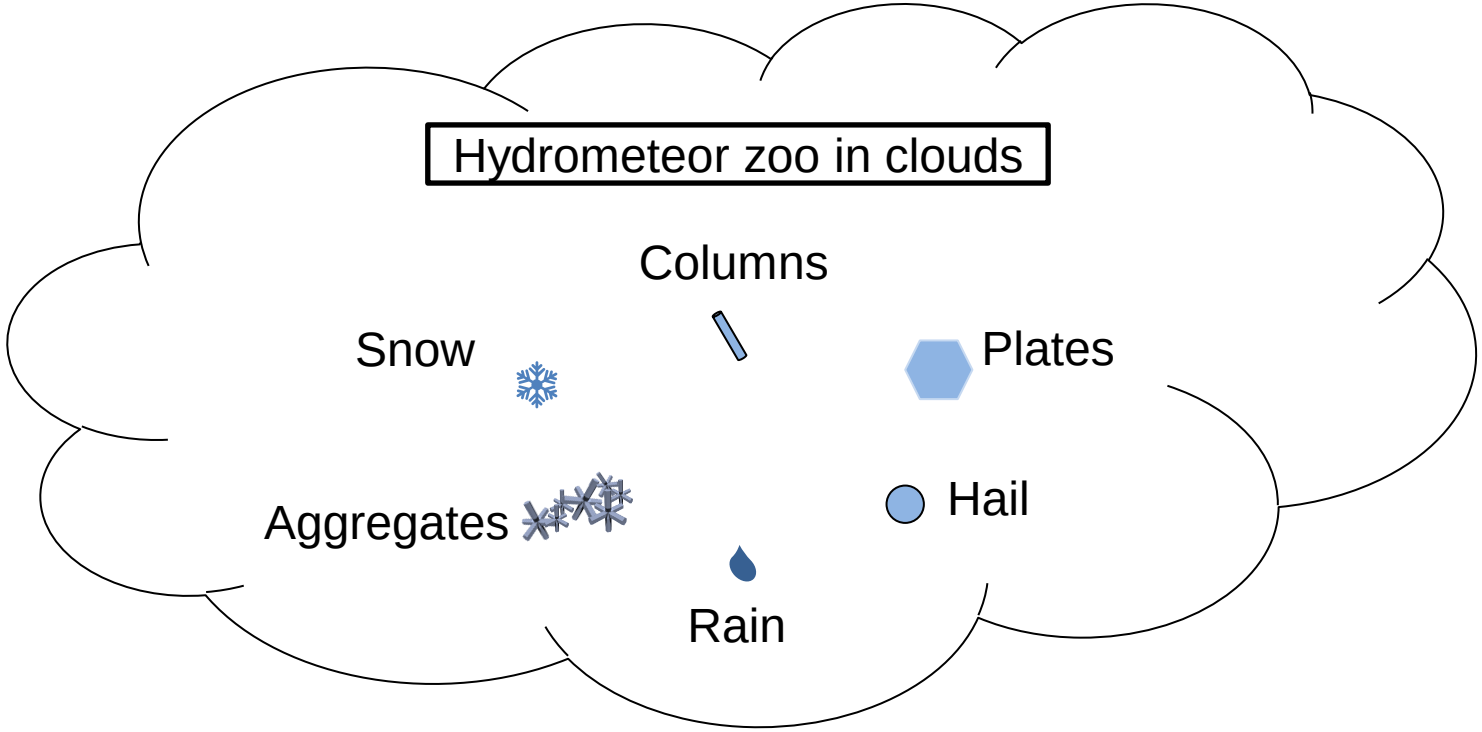


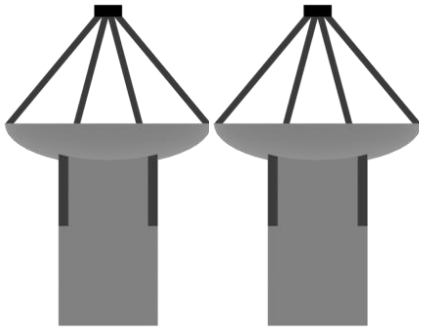
# Motivation: Radar geometry to constrain microphysics




One Radar:
Not enough to properly constrain microphyscis

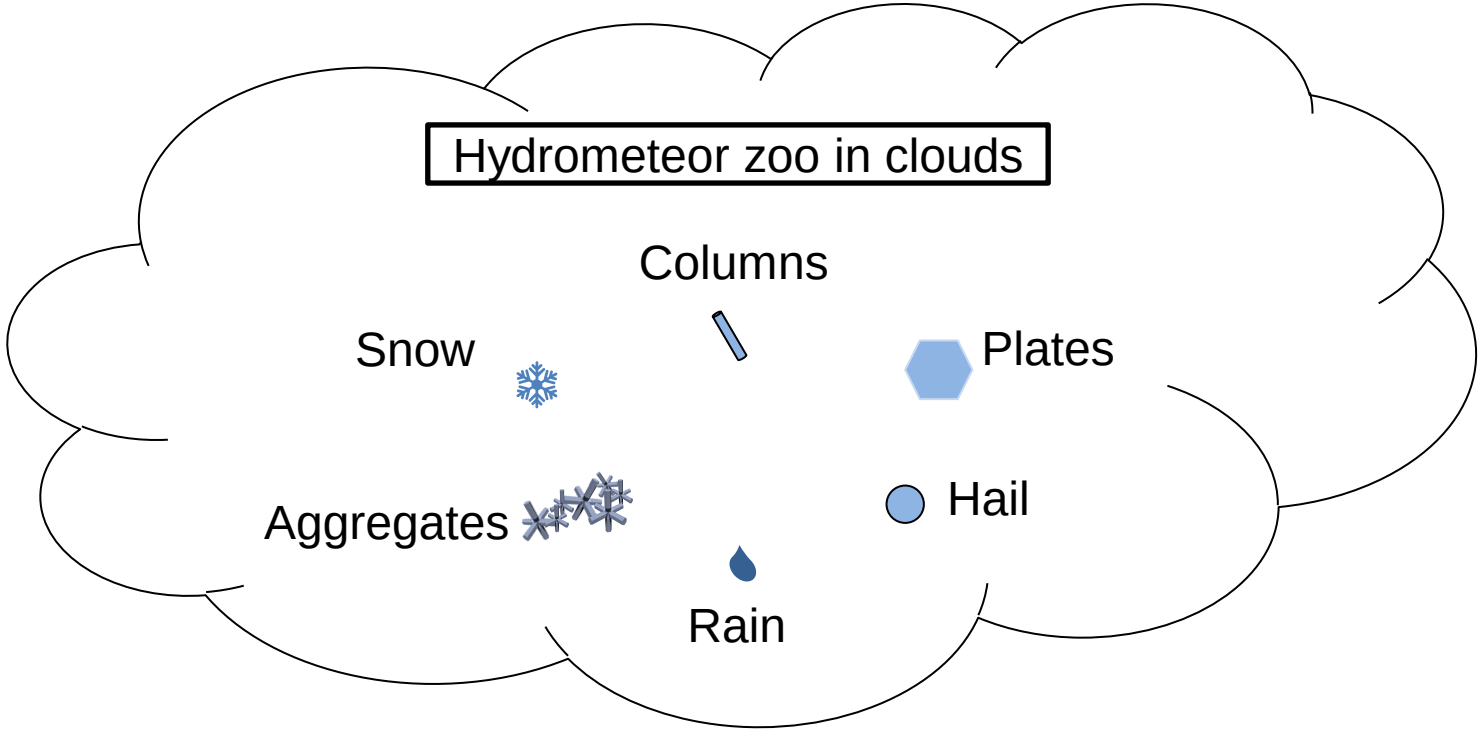
# Motivation: Radar geometry to constrain microphysics

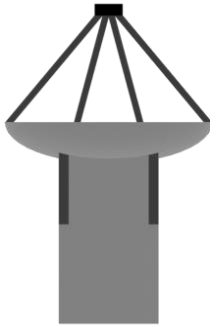


Multi-wavelength approach: Hydrometeors look spherical from below -> shape assumption necessary

# Motivation: Radar geometry to constrain microphysics



Multiwavelength + Polarimetry from oblique perspective:
No shape assumption necessary
Fall speeds + LDR measurements

# Phase 1: Summary

**Data**

RHI data of C-band and Ka-band radars pointing to each other

# Phase 1: Summary

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