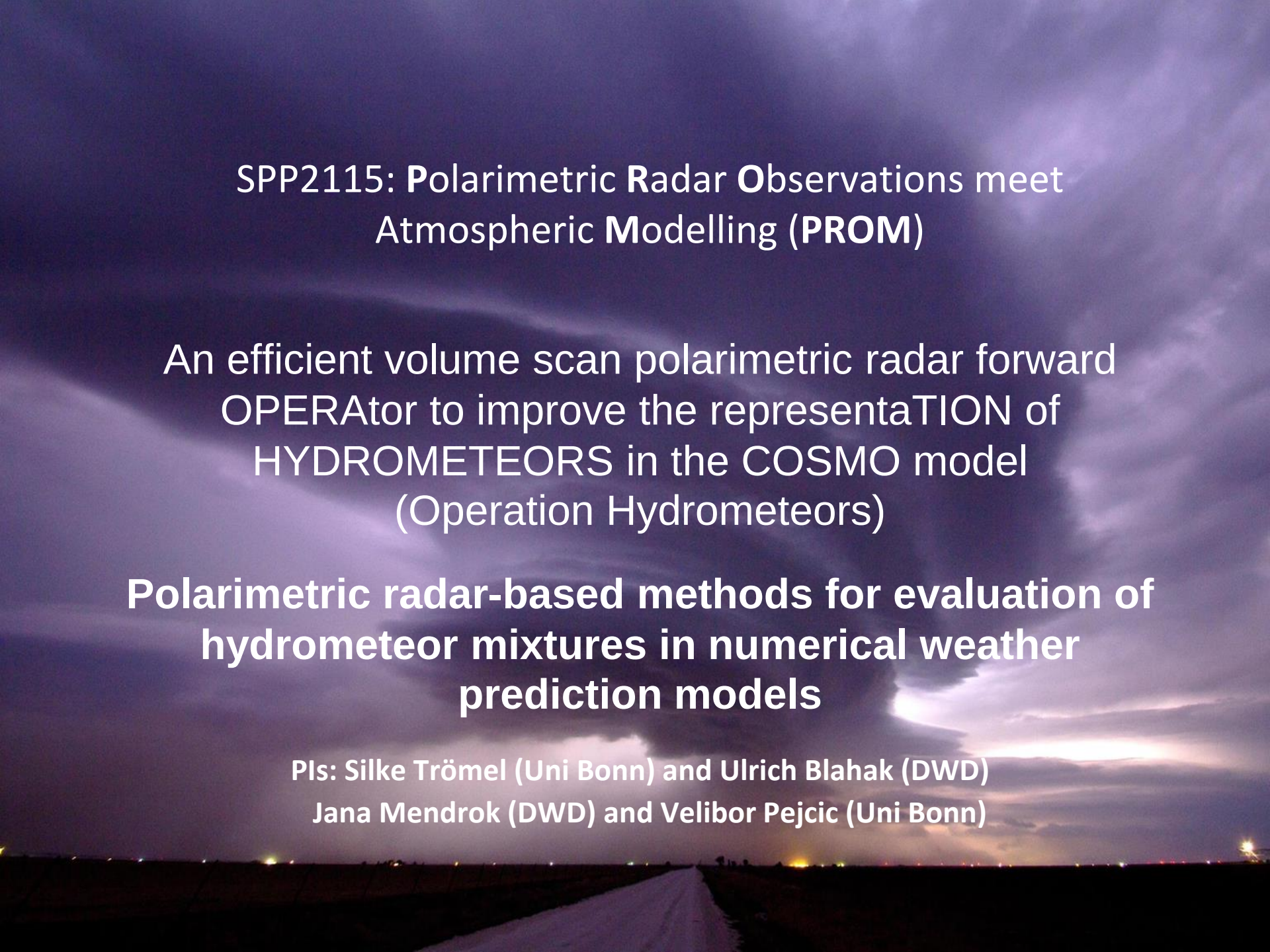


SPP2115: **P**olarimetric **R**adar **O**bservations meet Atmospheric **M**odelling (**PROM**)

An efficient volume scan polarimetric radar forward OPERAtor to improve the representaTION of HYDROMETEORS in the COSMO model (Operation Hydrometeors)

Polarimetric radar-based methods for evaluation of hydrometeor mixtures in numerical weather prediction models

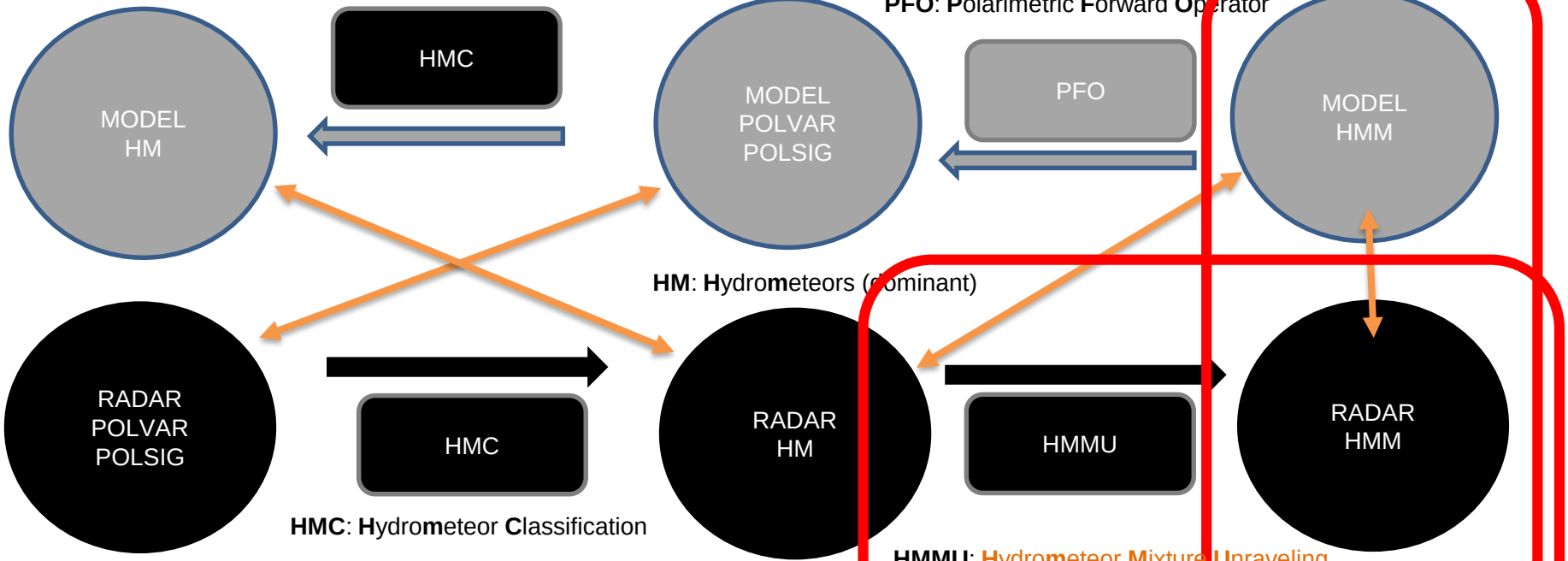
PIs: Silke Trömel (Uni Bonn) and Ulrich Blahak (DWD)
Jana Mendrok (DWD) and Velibor Pejcic (Uni Bonn)

Comparing challenges and strategies

institut für geowissenschaften METEOROLOGIE
UNIVERSITÄT BONN

HMM: **H**ydro**m**eteor **M**ixtures

PFO: **P**olarimetric **F**orward **O**perator



POLVAR: **Pol**arimetric **Var**iables
POLSIG: **Pol**arimetric **Sig**natures

Comparison:

- *Comparison between model and observations only statistically (**time/space shifts**)*
- The **A-priori** definition of different HM **classes and numbers**

Unphysical class attributions:

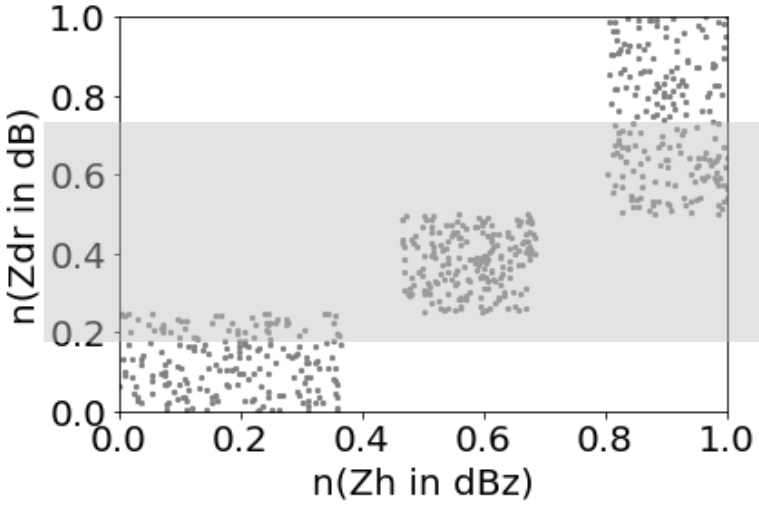
- ***Uncertain** of HM class properties define by **theoretical scattering simulations** (solid phase)*
  Tyynetla et al. 2011
- *Impact of radar observation **accuracy** on HM typing*
  Park et al. 2009

Reliability of HMs in mixtures:

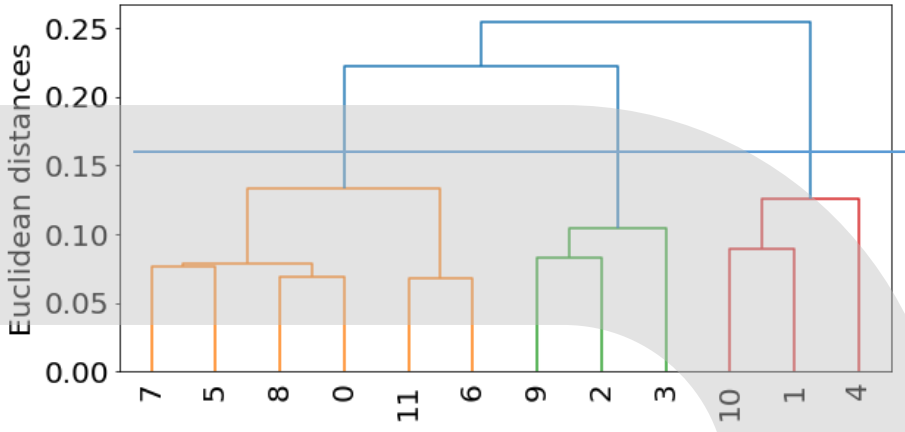
- *A **less represented** HM class may be identified as dominant in HM **mixtures** due to disproportional impact on PolVar*

Hydrometeor classification
1st Step: Clustering of polarimetric variables

$$X_{obs} = [Z_H, Z_{DR}, K_{DP}, \rho_{HV}, I(T)]$$

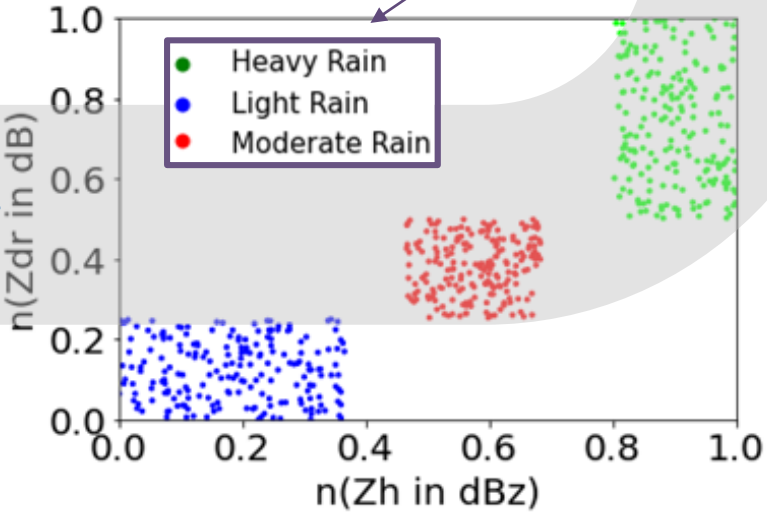


Agglomerative Hierarchical Clustering

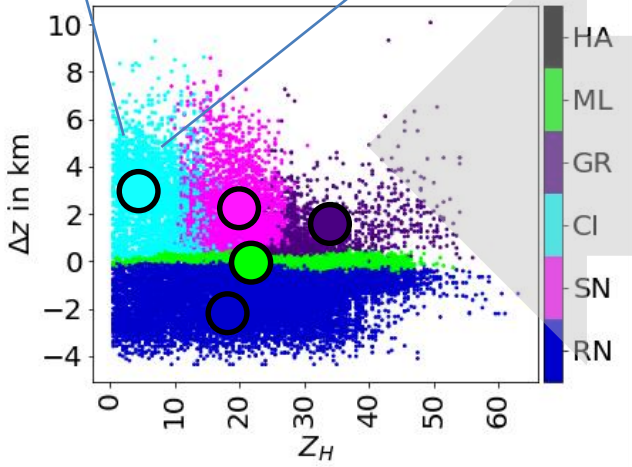


Optimal number of clusters

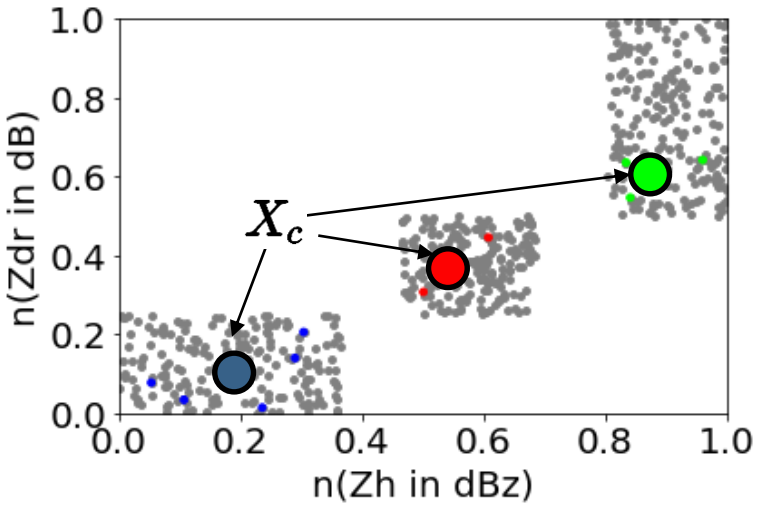
State-of-the-art HMCs for labeling



Centroid X_c & Covariance Σ



Hydrometeor classification
2nd: Determination of partitioning ratios



$$X_{obs} = [Z_H, Z_{DR}, K_{DP}, \rho_{HV}, I(T)]$$

Exponential Distribution (Controids, Besic et al. 2018)

$$p_i = e^{-t_i d_i}, i = 1, \ldots n_{\text{clusters}}$$

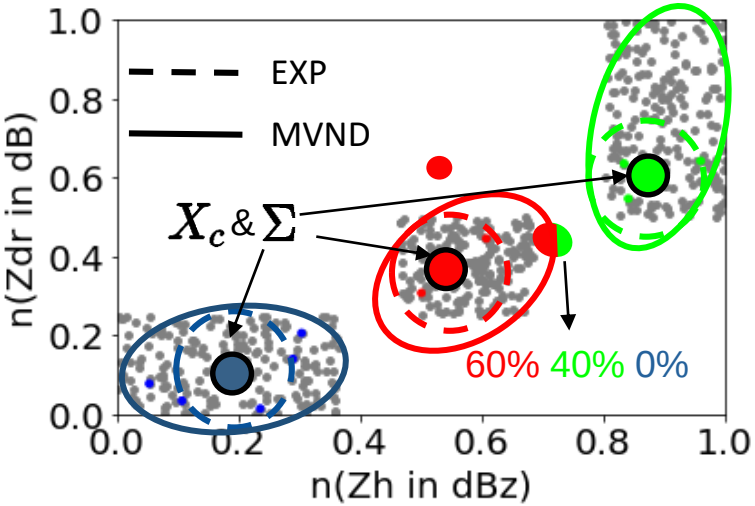
$n_{clusters}$: Number of clusters/hydrometeor classes

p_i: Probability/mixing ratio of a hydrometeorclass i

d_i: Euclidean distance to cluster i

t_i: Probability adjustment

Hydrometeor classification
2nd: Determination of partitioning ratios



$$X_{obs} = [Z_H, Z_{DR}, K_{DP}, \rho_{HV}, I(T)]$$

Exponential Distribution (Controids, Besic et al. 2018)

$$p_i = e^{-t_i d_i}, i = 1, \ldots n_{\text{clusters}}$$

$n_{clusters}$: Number of clusters/hydrometeor classes

p_i: Probability/mixing ratio of a hydrometeorclass i

d_i: Euclidean distance to cluster i

t_i: Probability adjustment

Multivariate Normal Distribution (Centroids + Covariances)

$$p_i(\mathbf{X_{obs}} \mid X_{ci}, \Sigma_i) = \frac{1}{\sqrt{(2\pi)^d |\Sigma_i|}} \exp\left(-\frac{1}{2}(\mathbf{X_{obs}} - X_{ci})^T \Sigma_i^{-1} (\mathbf{X_{obs}} - X_{ci})\right)$$

$i = 1, \ldots, n_{clusters}$

$n_{clusters}$: Number of clusters/hydrometeor classes

d: Size of observation

Σ: Covariance matrix

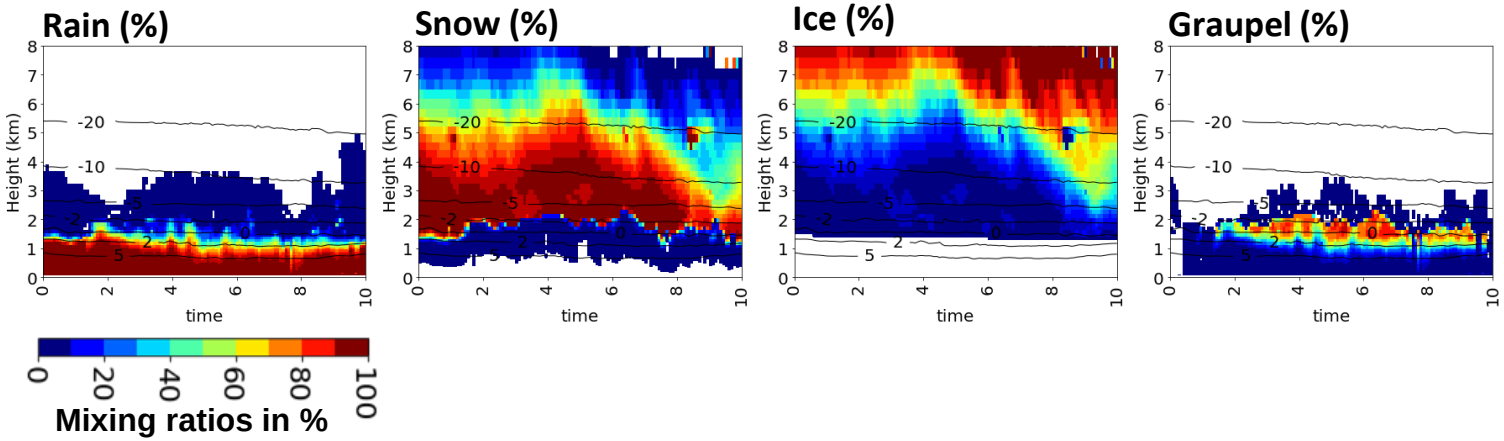
X_{obs}: Observation

X_c: Centroid

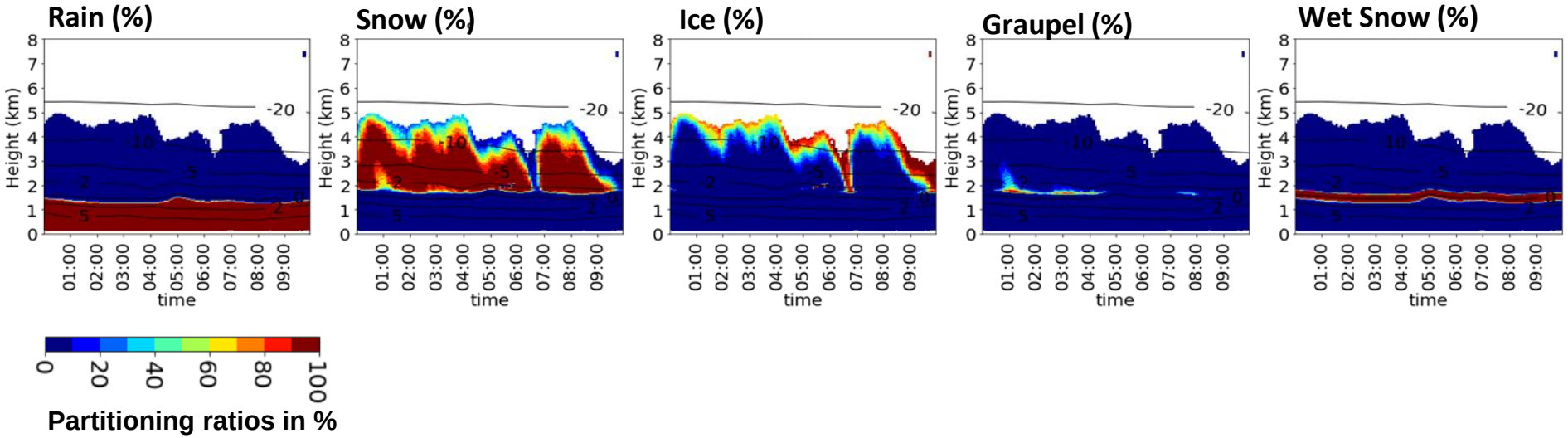
Comparison of polarimetry-based HM-partitioning ratios with model mixing ratios

institut für geowissenschaften METEOROLOGIE
UNIVERSITÄT BONN

MODEL (ICON) - Mass concentration in kg/kg as Mixing Ratios (q-based)



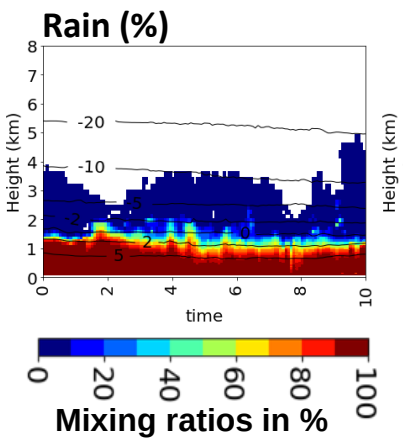
RADAR (BoXPol) - HMC-Pejcic

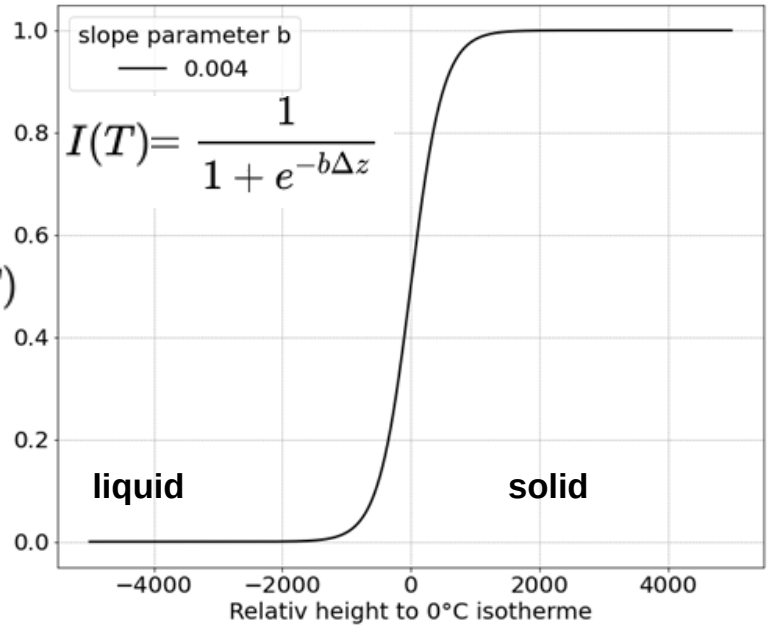


Comparison of polarimetry-based HM-partitioning ratios with model mixing ratios

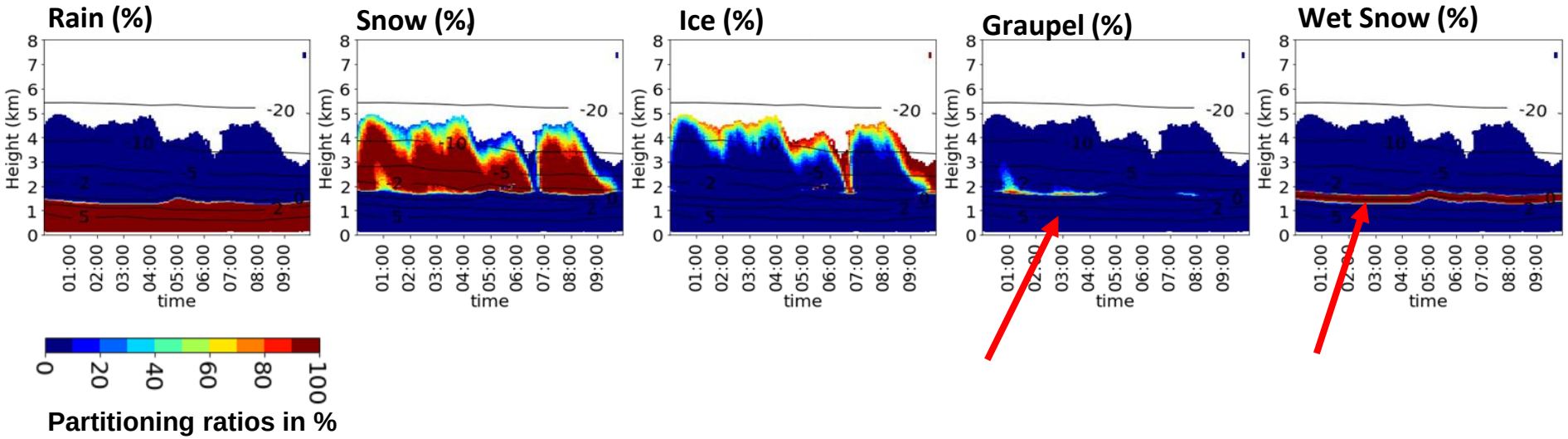
institut für geowissenschaften METEOROLOGIE
UNIVERSITÄT BONN

MODEL (ICON) - Mass concentration in kg/kg as Mixing Ratios (q-k



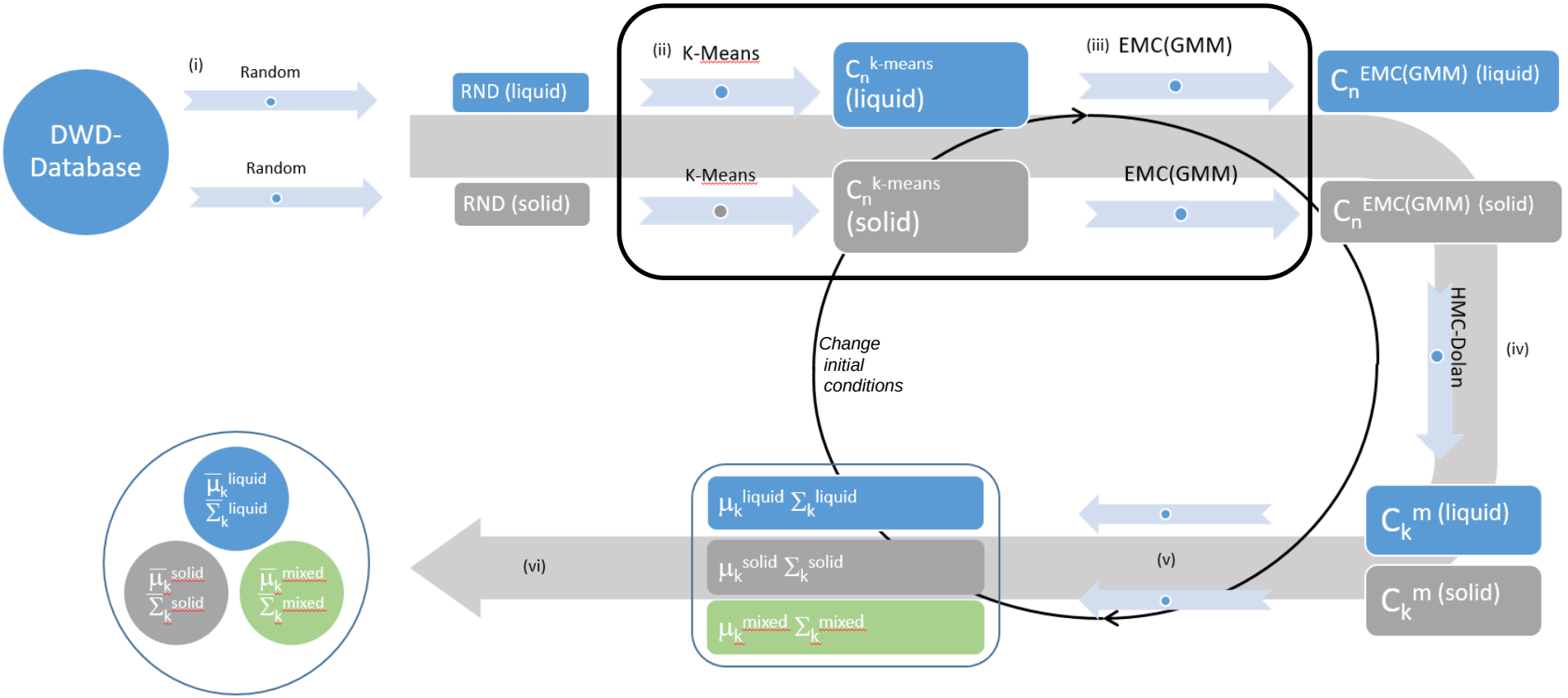


RADAR (BoXPol) - HMC-Pejcic



Refinements of HMC-Pejcic
The 0°C-challenge

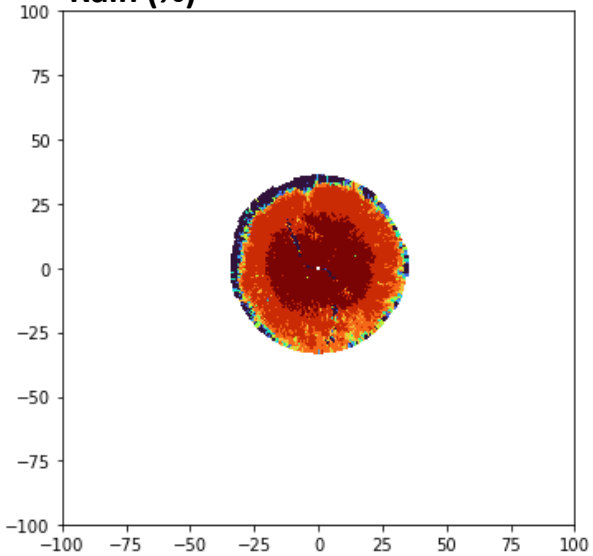
New Clustering: Expectation-Maximization Clustering (EMC) based on Gaussian Mixture Models(GMM)



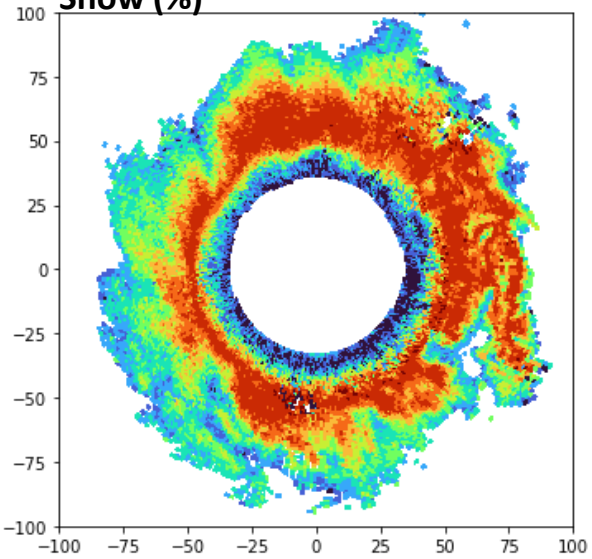
Refinements of HMC-Pejcic
The 0°C-challenge

institut für geowissenschaften METEOROLOGIE
UNIVERSITÄT BONN

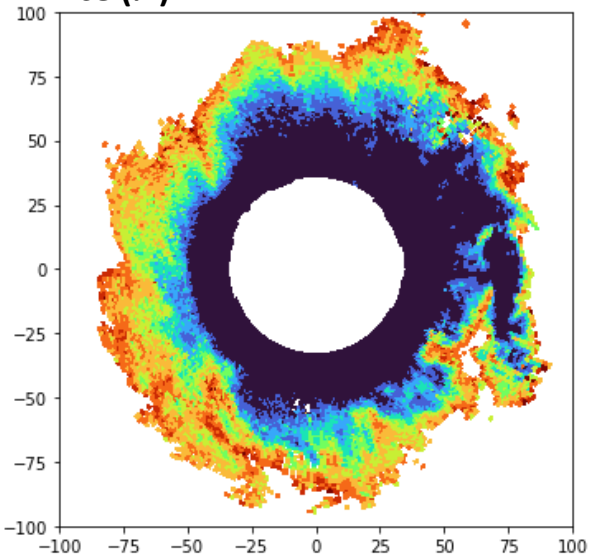
Rain (%)



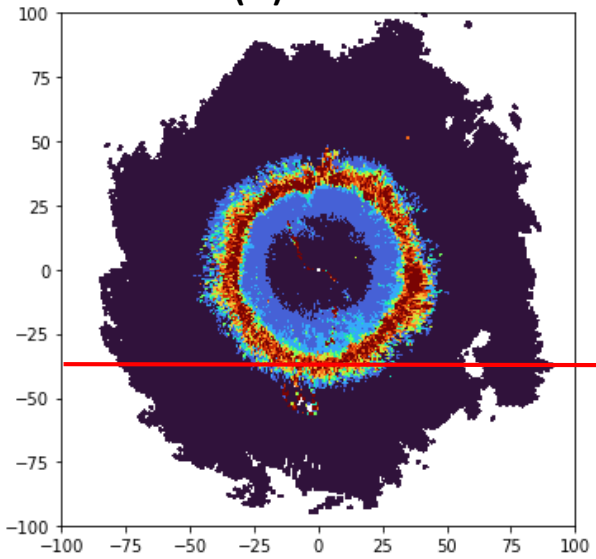
Snow (%)



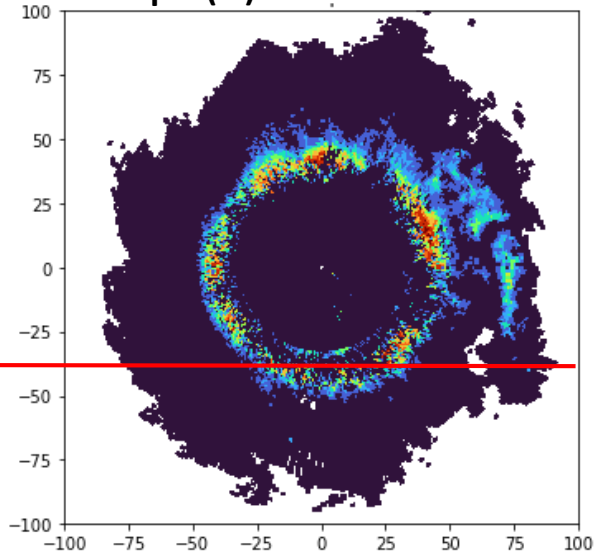
Ice (%)



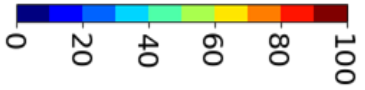
Wet Snow (%)



Graupel (%)



Partitioning ratios in %



C-band: 2017-07-25
Location: Prötzel
Elevation: 1.5°

Summary and Outlook

institut für geowissenschaften METEOROLOGIE
UNIVERSITÄT BONN

- We developed a **sophisticated clustering-based HMC** adapted to the number and types of HM in the model, which allows to estimate also **HM partitioning ratios** from radar observations.

- **Verification** of the reliability of polarimetry-based HMC for **HM partitioning with synthetic data** (previous talk).

- **Overestimated graupel** generation around the melting layer in the model. Other evaluation results already shown in previous talks.

Thank you for your attention!

- More comparisons of **polarimetric variables** (CFAD), **dominant hydrometeor** types and **partitioning ratios** (profiles) including stratiform and **convective** cases.

- Refining the HMC-Pejcic by: (i) replacing **clustering method** to better consider the **shape of the clusters** during clustering and (ii) perform the **clustering independently** of the **temperature indicator** by processing the **solid** and **liquid** regions **independently** of each other.

- **Evaluation and improved representation** of key polarimetric signatures in **convection**, dendritic growth (**DGL**) and melting layer (**ML**).

- Is the **detection** of **supercooled liquid water** in updrafts (Big rain drops in ZDR columns) possible?