Evaluation of hydrometeor types and properties in the ICON-LAM model with polarimetric radar observations (Operation Hydrometeors)

institut für geowissenschaften
METEOROLOGIE
UNIVERSITÄT BONN

V. PEJCIC, S. TRÖMEL, C. SIMMER (UNI BONN)

J. MENDROK, U. BLAHAK (DWD)

Comparing challenges and strategies

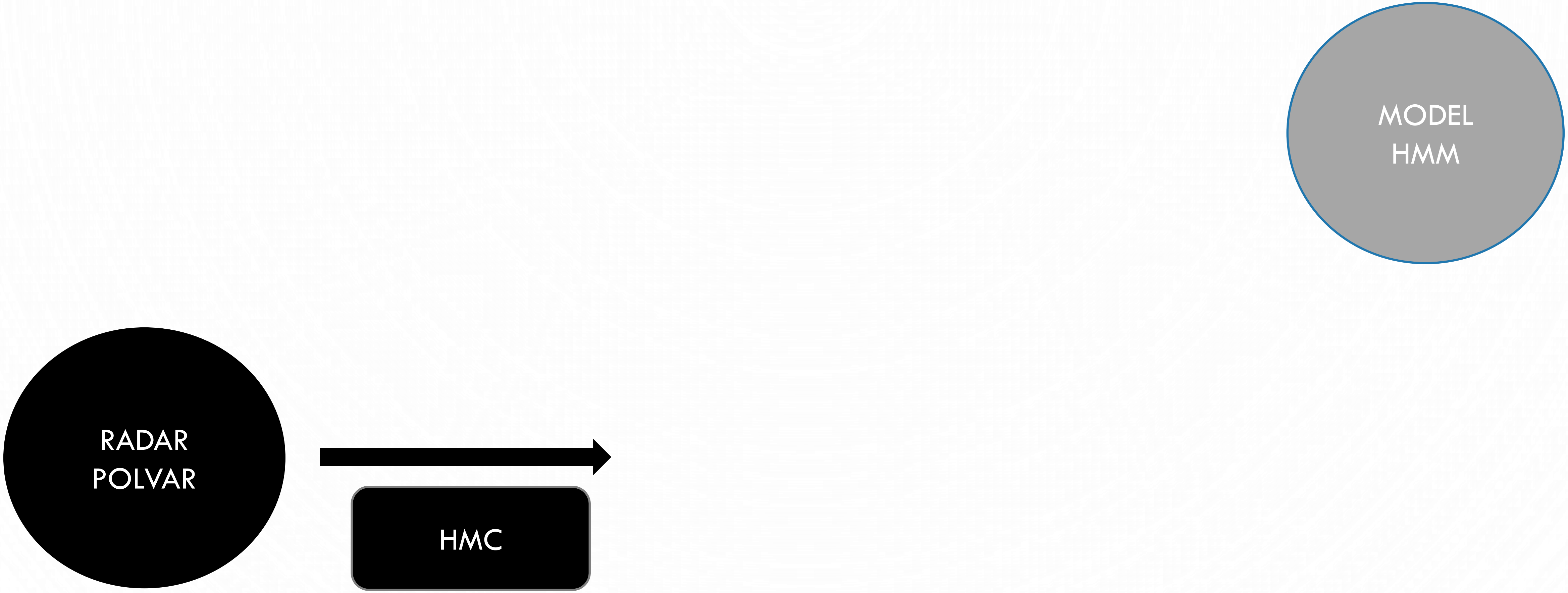
HMM: **H**ydrometeor **M**ixtures

MODEL
HMM

RADAR
POLVAR

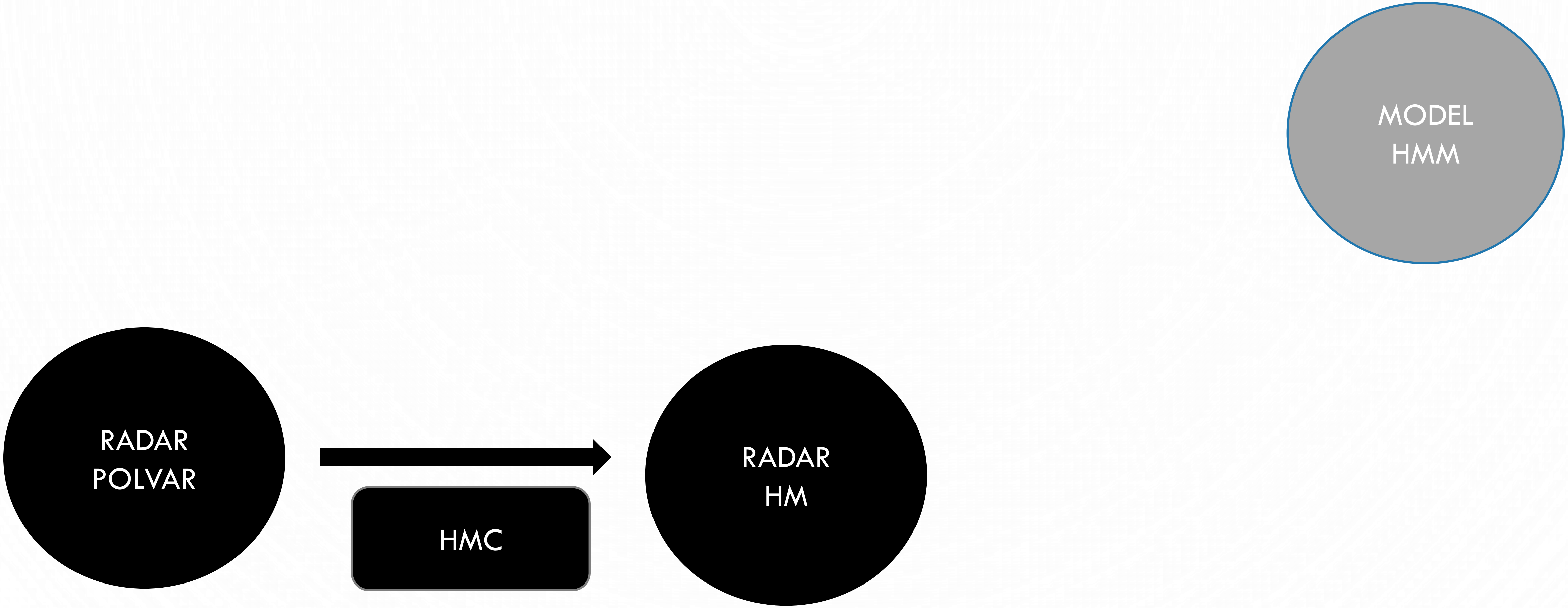
POLVAR: **Po**larimetric **Var**iables

Comparing challenges and strategies



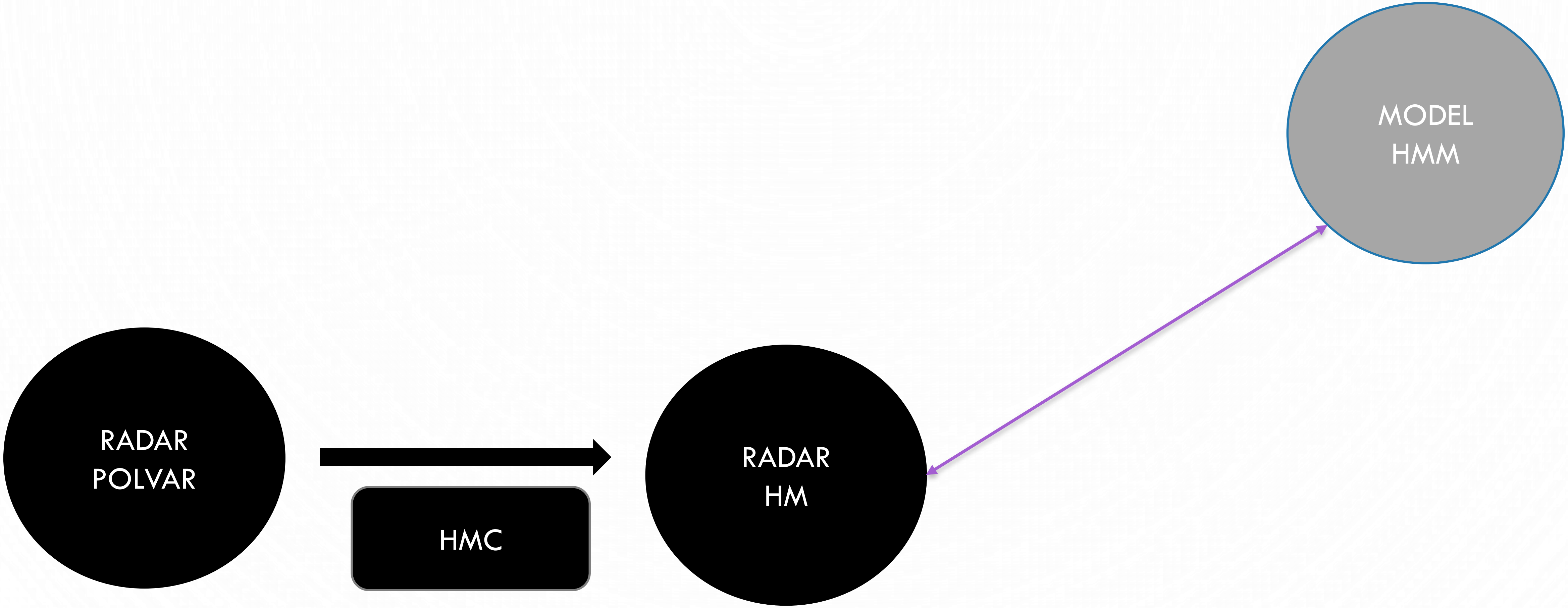
HMC: **H**ydrometeor **C**lassification

Comparing challenges and strategies



HMC: **H**ydrometeor **C**lassification

Comparing challenges and strategies



HMC: **H**ydrometeor **C**lassification

Comparing challenges and strategies

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

MODEL
HMM

RADAR
POLVAR

HMC

RADAR
HM

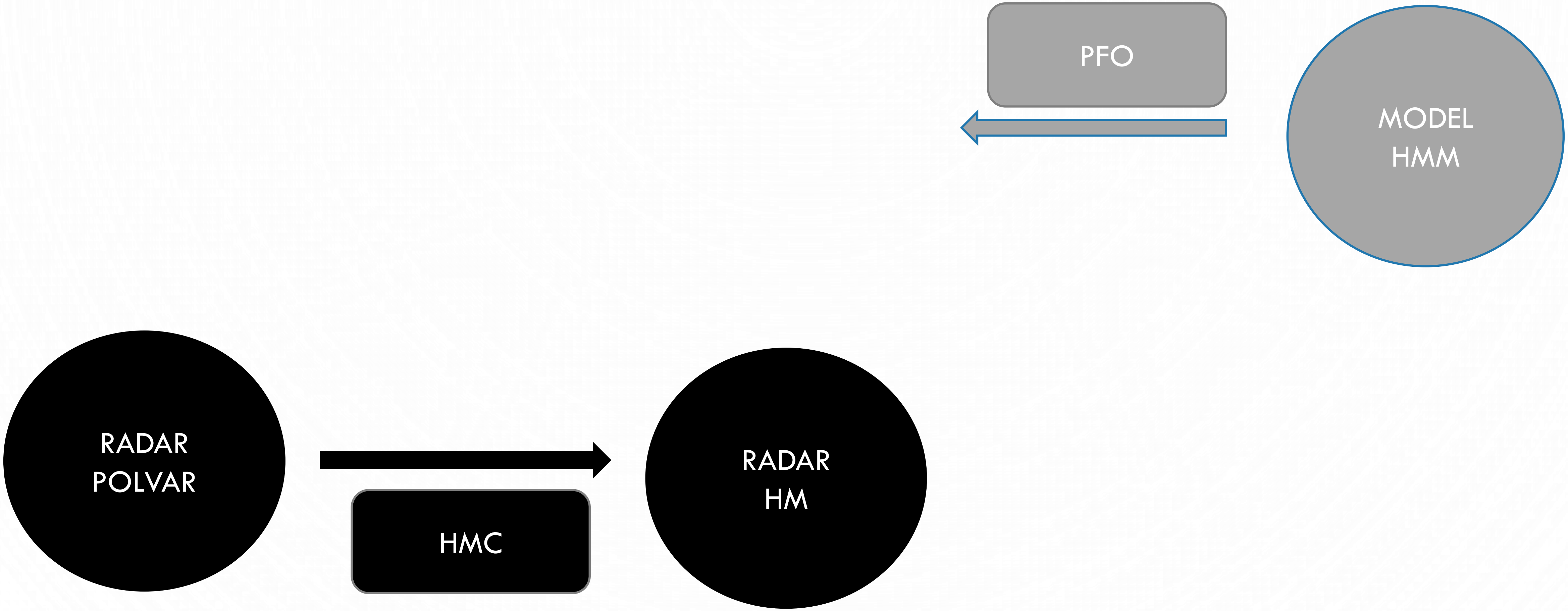
HMC: **H**ydrometeor **C**lassification

Reliability of HMs in mixtures:

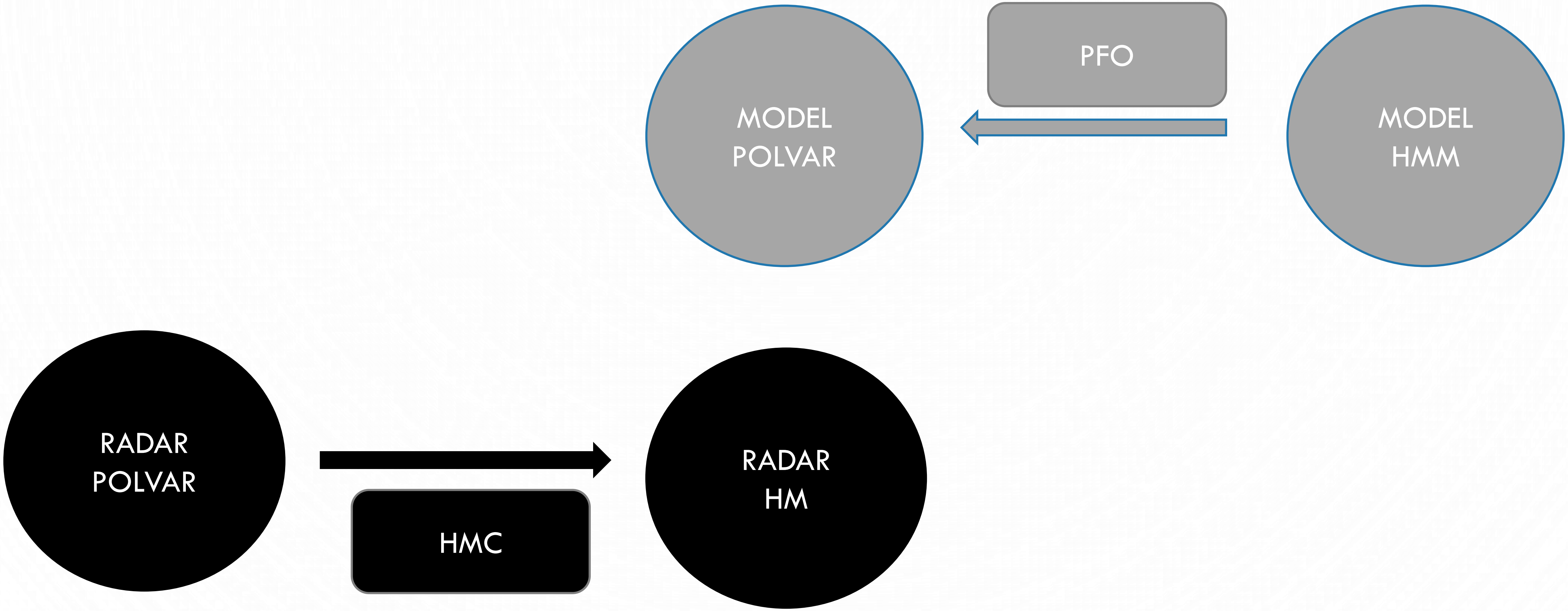
- *A **less represented** HM class may be identified as dominant in HM mixtures due to disproportional impact on PolVar*

Comparing challenges and strategies

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

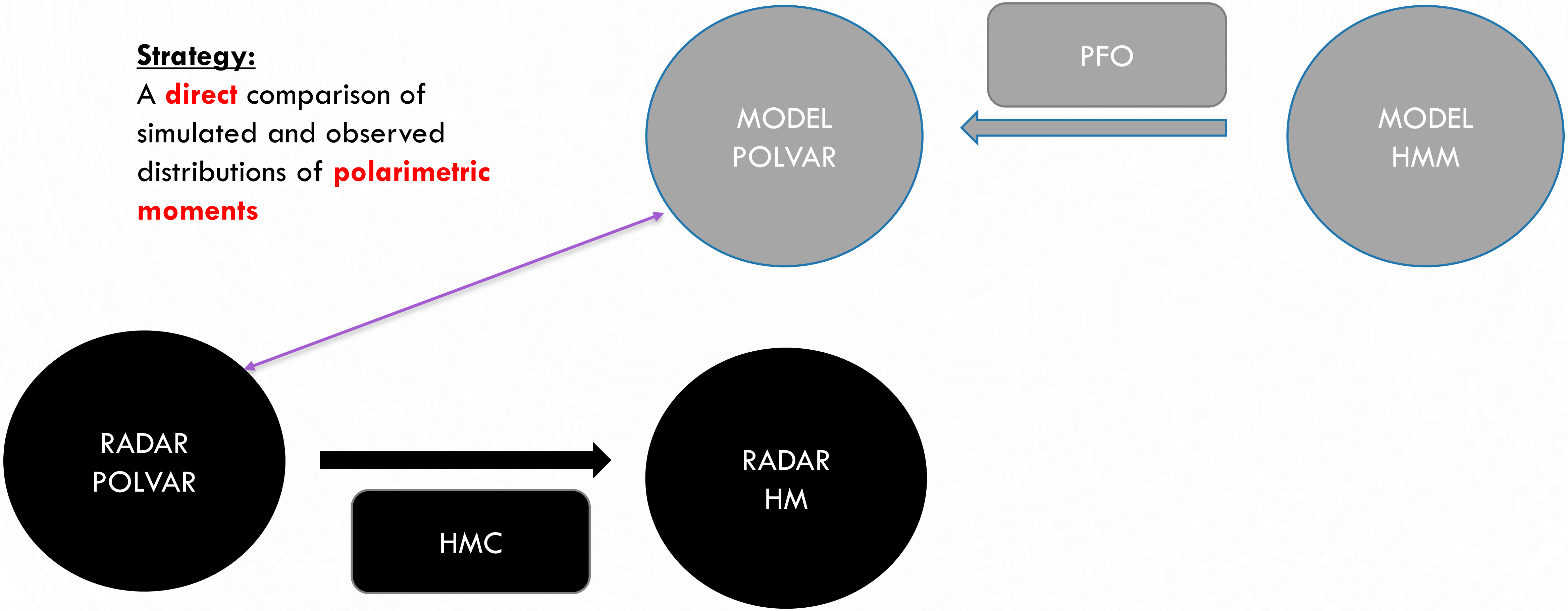


Comparing challenges and strategies

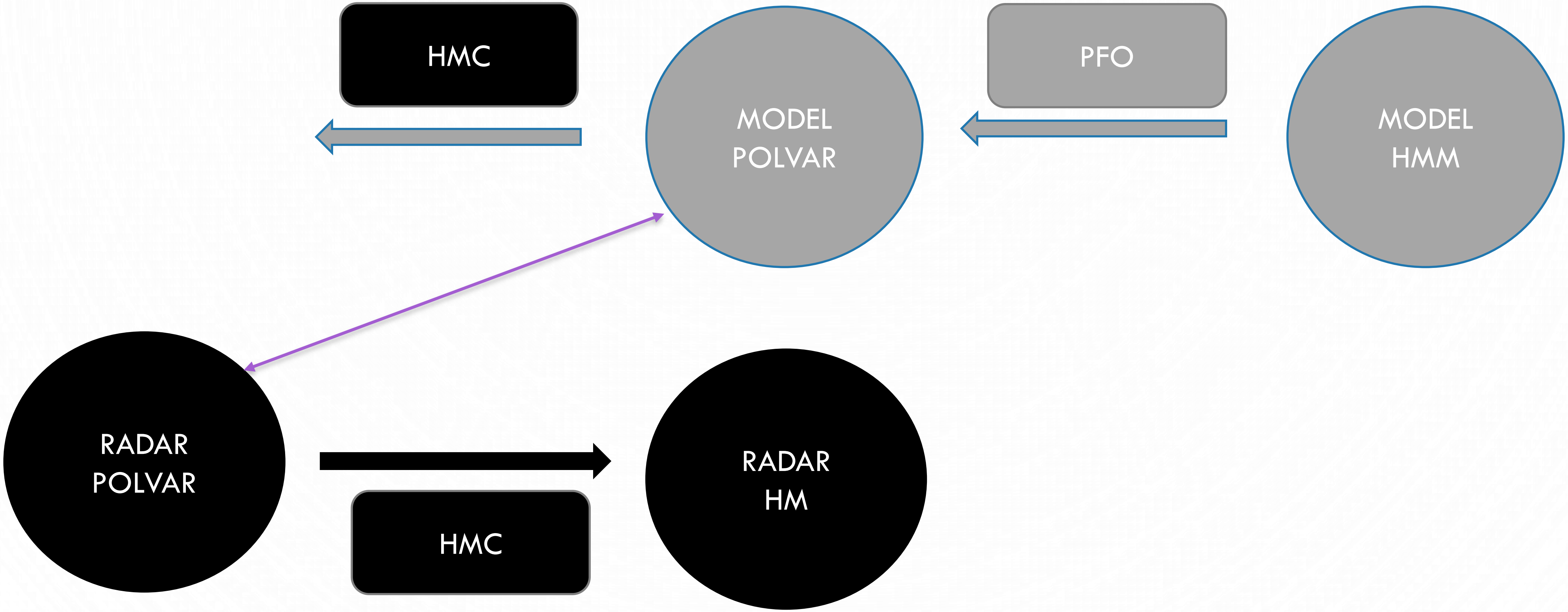


Comparing challenges and strategies

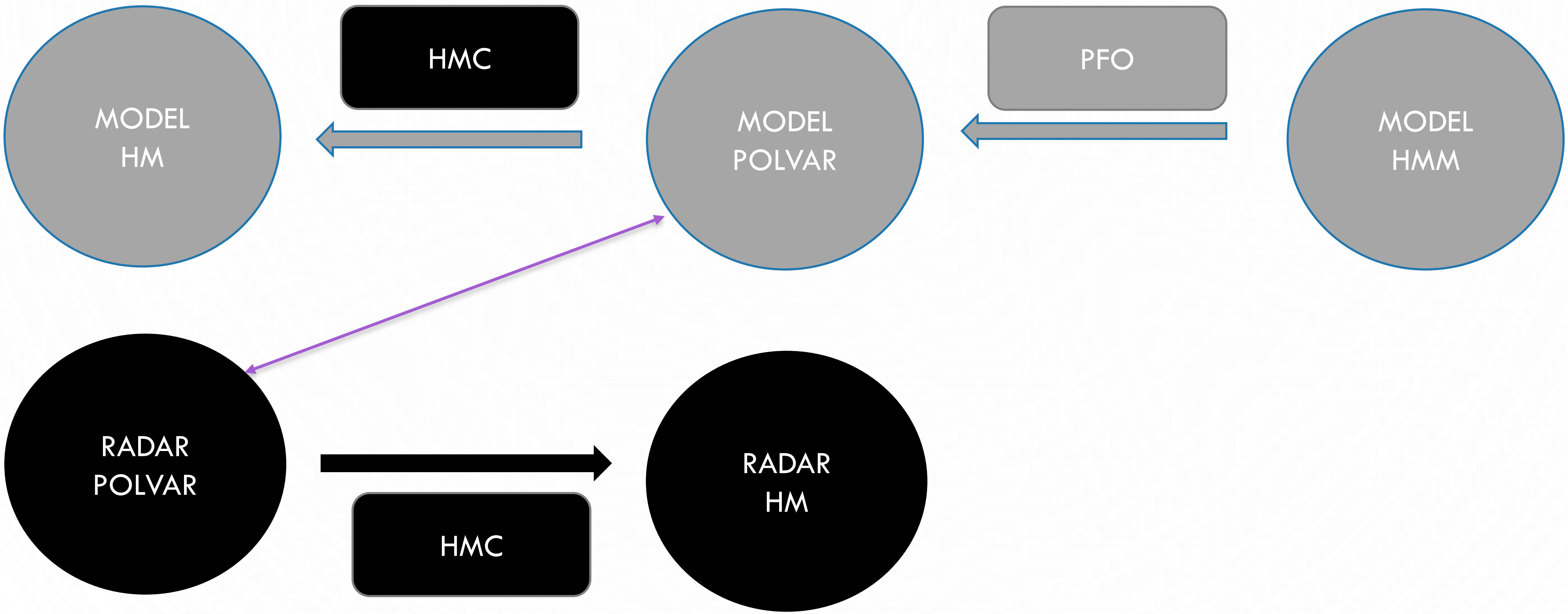
Strategy:
A **direct** comparison of simulated and observed distributions of **polarimetric moments**



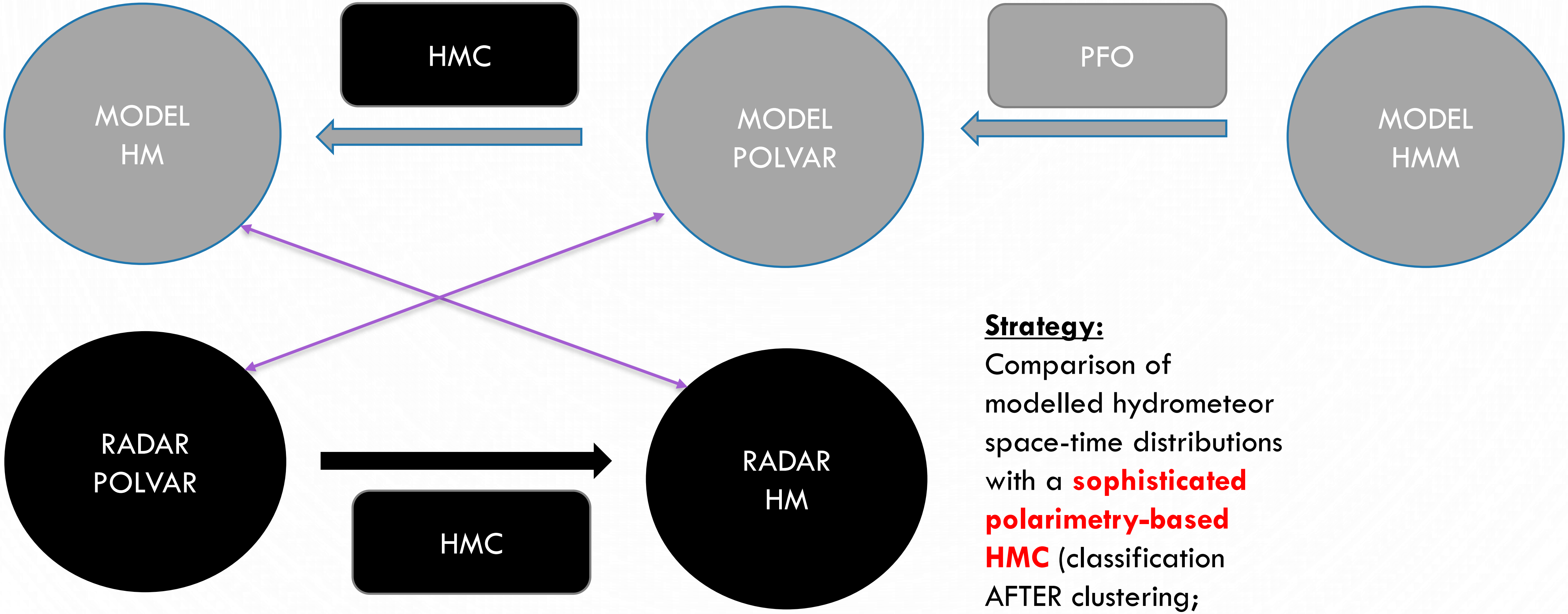
Comparing challenges and strategies



Comparing challenges and strategies

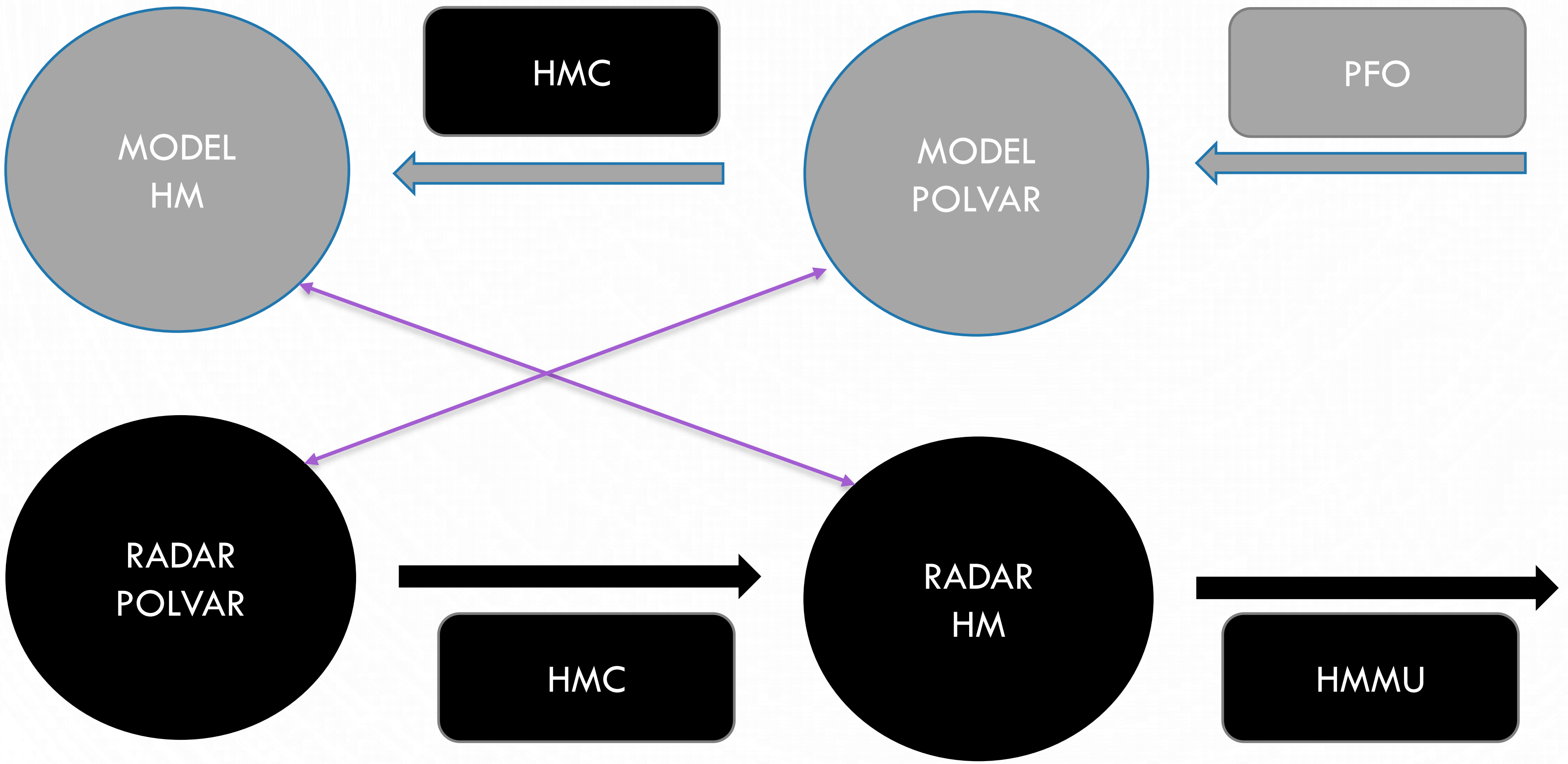


Comparing challenges and strategies



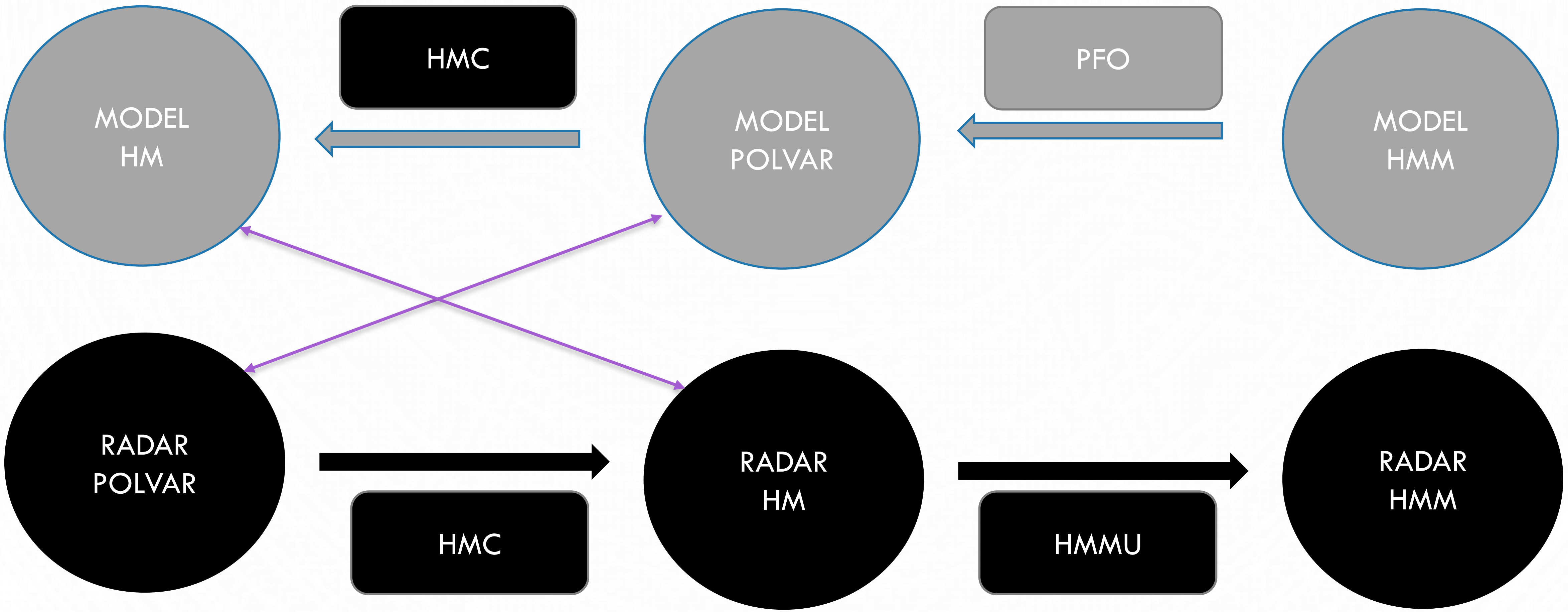
Strategy:
Comparison of modelled hydrometeor space-time distributions with a **sophisticated polarimetry-based HMC** (classification AFTER clustering; Grazioli et al. 2015)

Comparing challenges and strategies

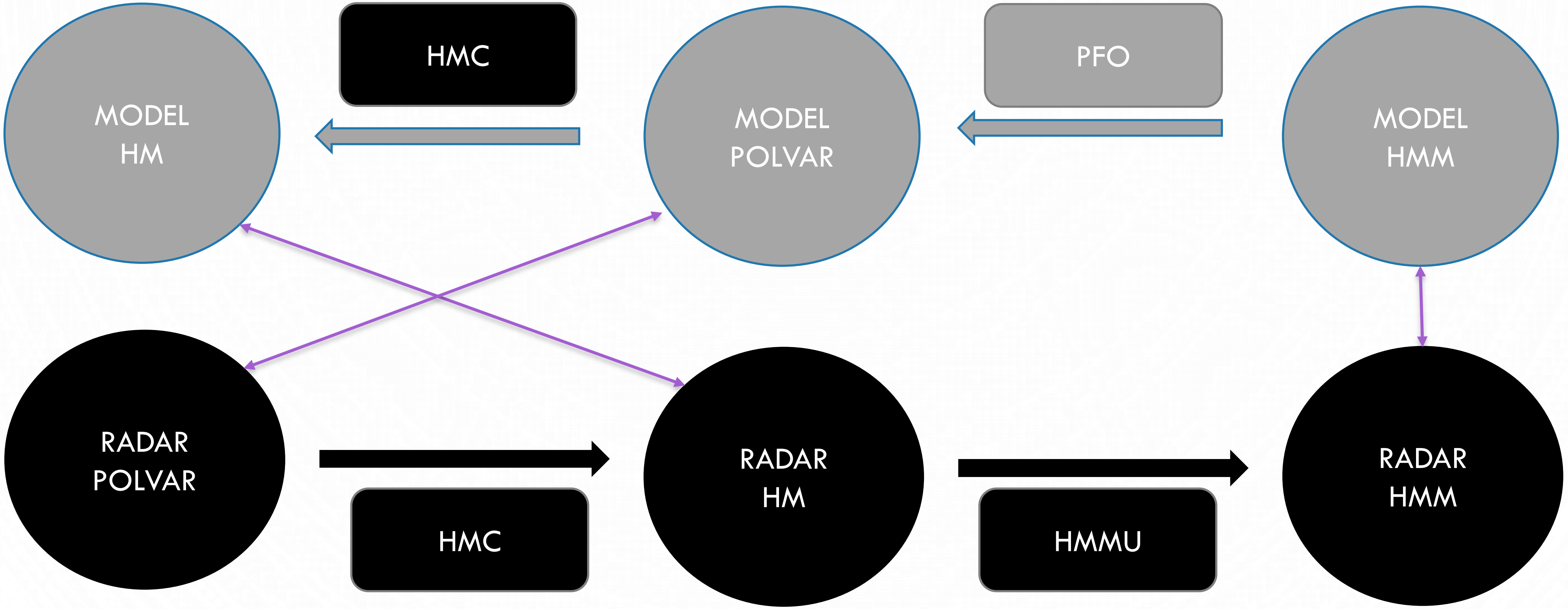


HMMU: **H**ydrometeor **M**ixture **U**nraveling (Besic et al. 2018)

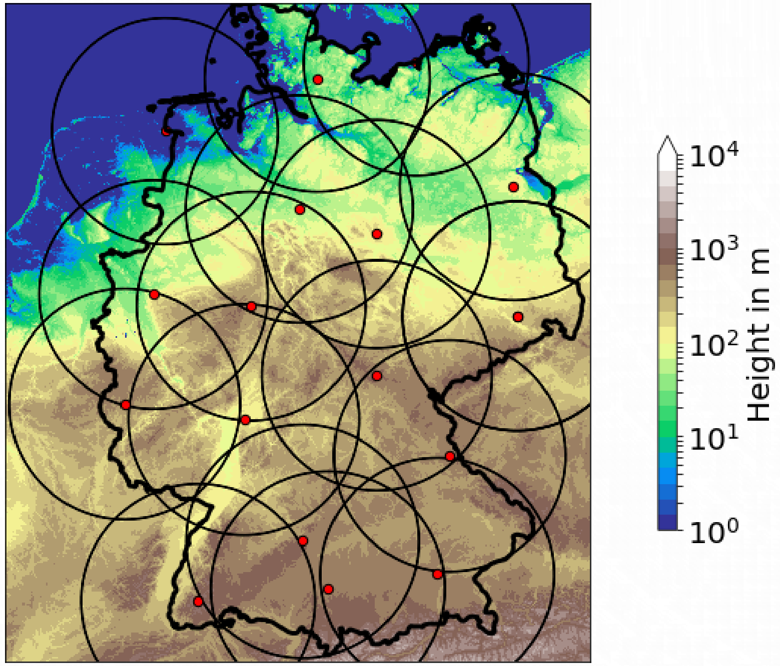
Comparing challenges and strategies

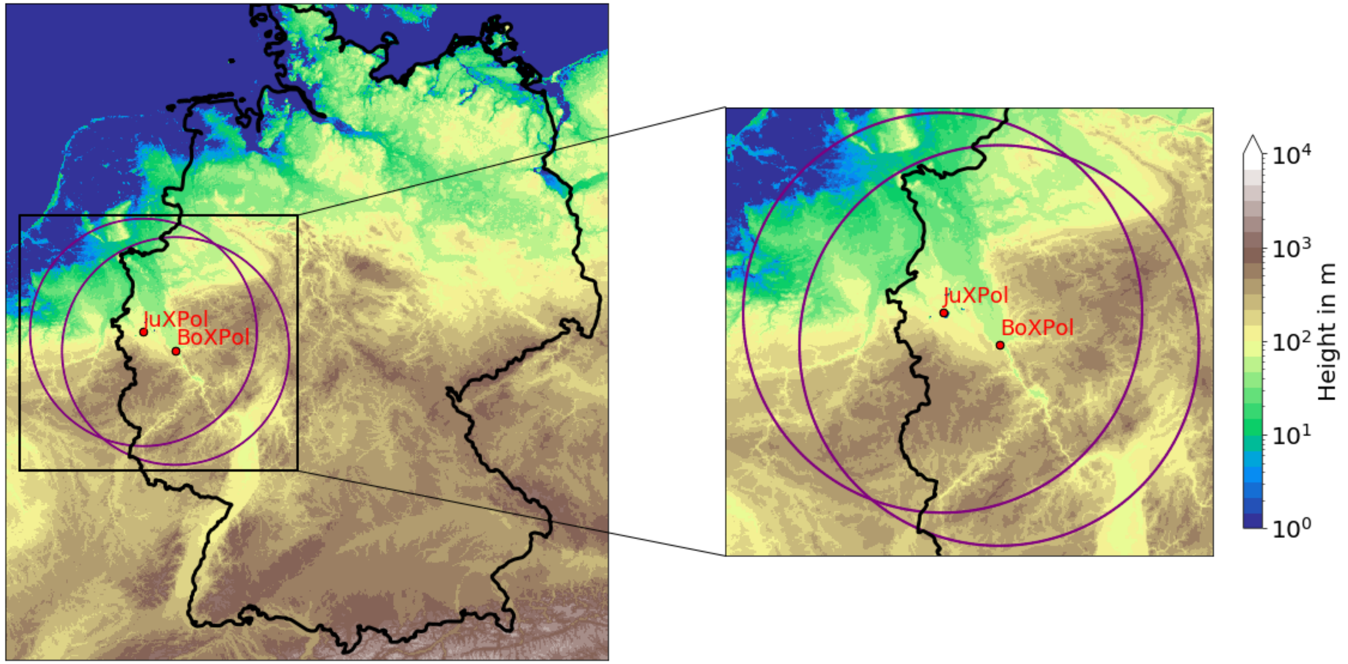


Comparing challenges and strategies



Radar Data

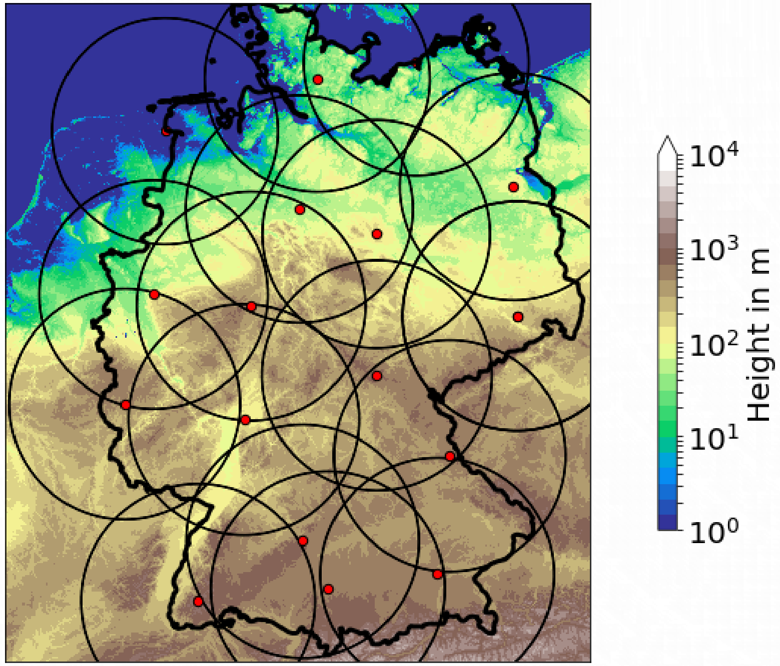




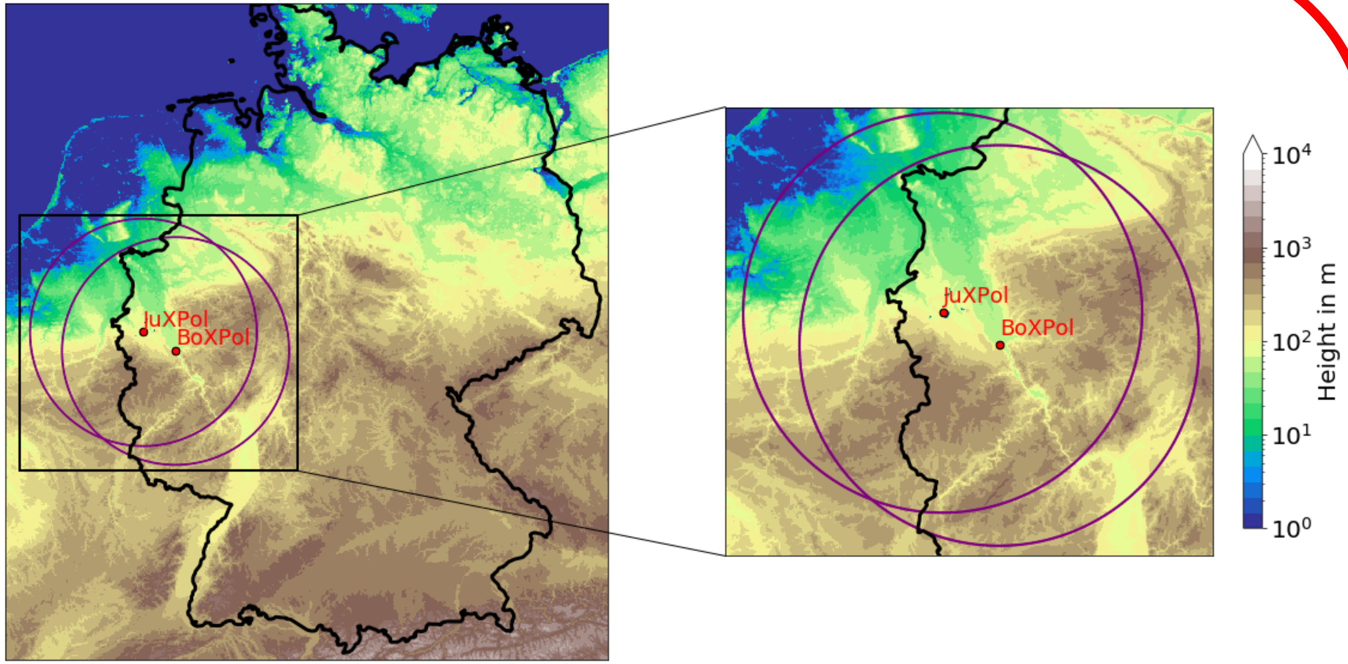
Radars: 17 dual-pol C-band
Resoution: 5 min x 1° x 1km
Frequenz: ~5 GHz
Elevation: terrain following (0.5° – 1.8°)
Range: 150 km
Composit: 1km x 1km x 0.25km x 5min

Radar: 2 dual-pol X-band
Resoution: 5 min x 1° x [25m – 150m]
Frequenz: 9.3 GHz
Elevation: 10 (1° - 28°)
Range: 150km
Composit: 0.5km x 0.5km x 0.25 km x 5min

Radar Data

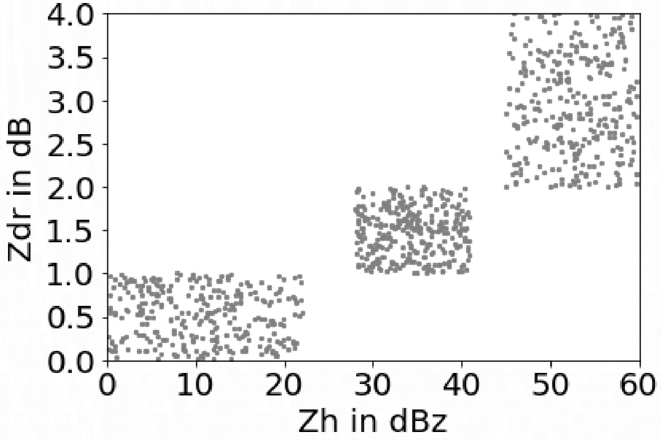


Radars: 17 dual-pol C-band
Resoution: 5 min x 1° x 1km
Frequenz: ~5 GHz
Elevation: terrain following (0.5° – 1.8°)
Range: 150 km
Composit: 1km x 1km x 0.25km x 5min



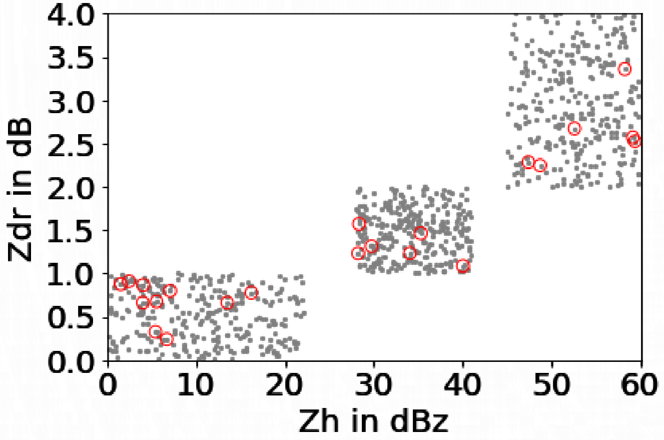
Radar: 2 dual-pol X-band
Resoution: 5 min x 1° x [25m – 150m]
Frequenz: 9.3 GHz
Elevation: 10 (1° - 28°)
Range: 150km
Composit: 0.5km x 0.5km x 0.25 km x 5min

Agglomerative Hierarchical Clustering (AHC)



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

Agglomerative Hierarchical Clustering (AHC)



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

Precipitation classification

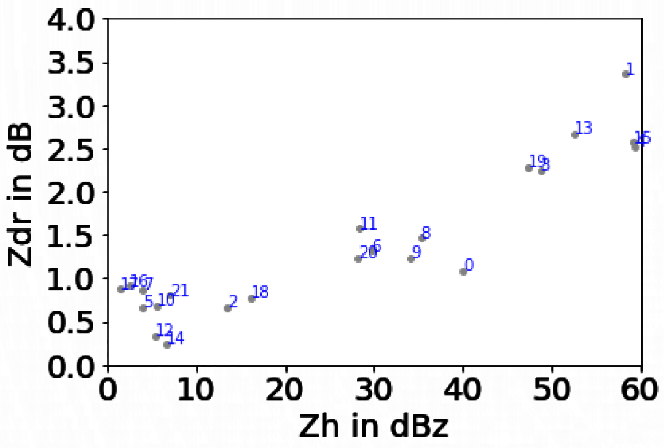
Stratiform/Convective

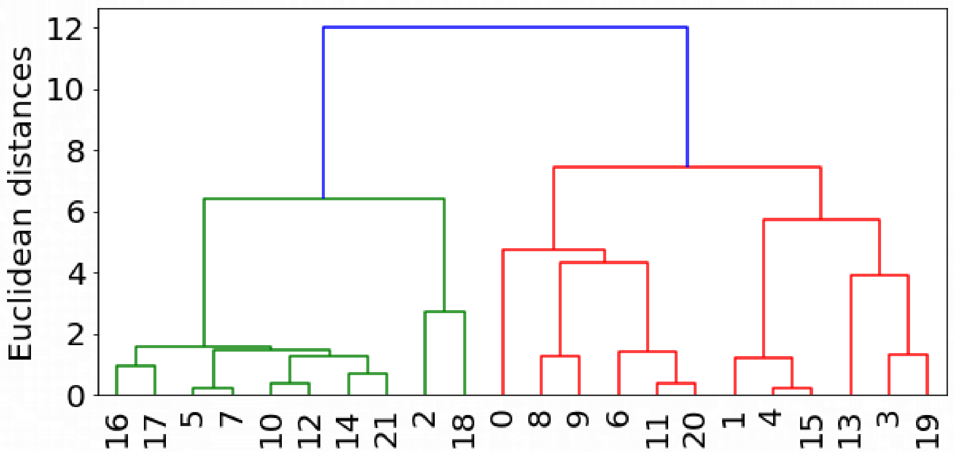
Steiner et al. 1995, Ribaud et al. 2019

Random Selection depending on Reflectivity

RND(Z) from reflectivity intervals
(0dBz to 70dBz in 2.5 dBz steps)

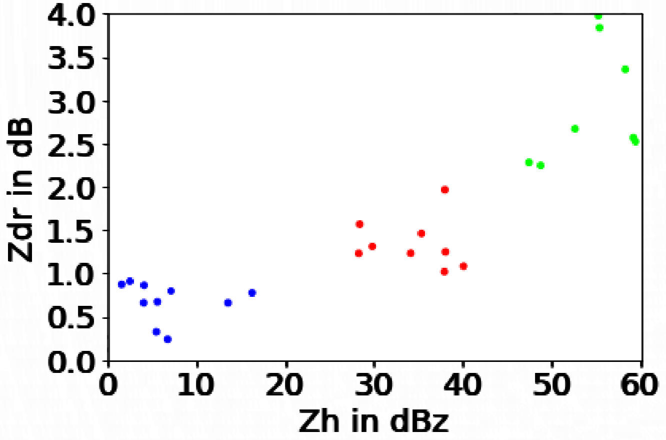
Agglomerative Hierarchical Clustering (AHC)

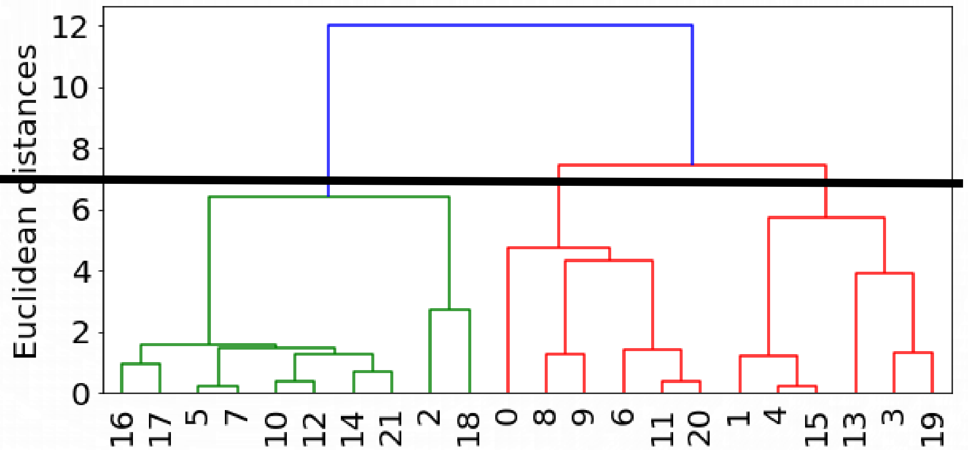




$$X_{obs} = [Z_H, Z_{DR}, K_{DP}, \rho_{HV}, I(T)]$$

Agglomerative Hierarchical Clustering (AHC)

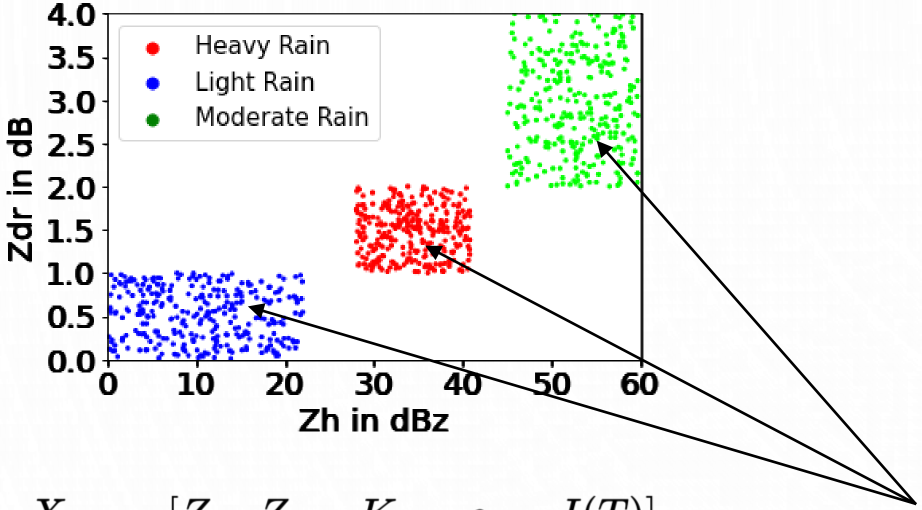


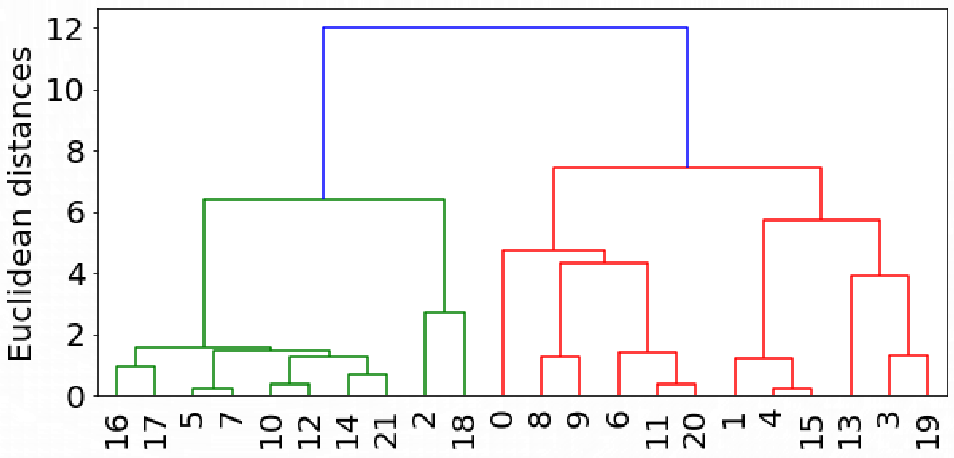


Optimal number of clusters

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

Agglomerative Hierarchical Clustering (AHC)



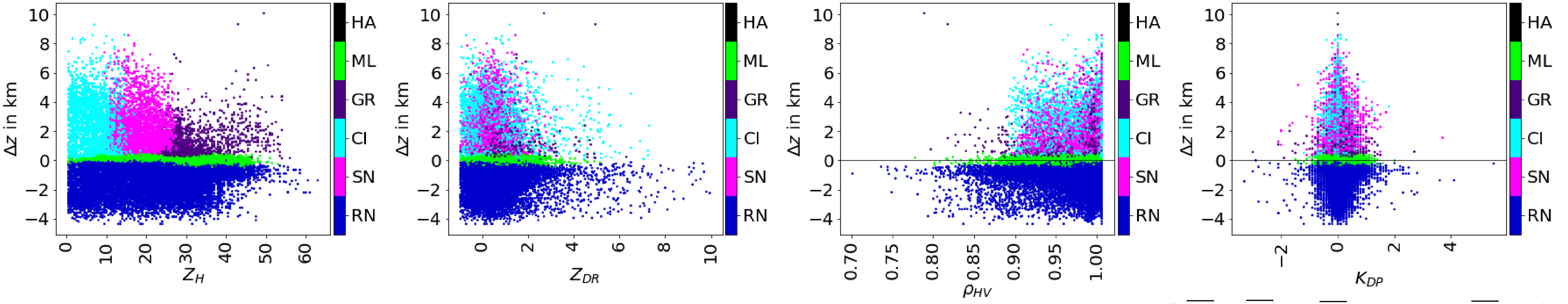


$$X_{obs} = [Z_H, Z_{DR}, K_{DP}, \rho_{HV}, I(T)]$$

- **State of the Art HMC** (Zrnic et al. 2001, Dolan and Rutledge 2009, Thompson et al. 2014)
- **Independent observation** (**2DVD** Grazioli et al. 2015, **Airborne in situ** Lukach et al. 2020)
- **Logical/physical conclusions**

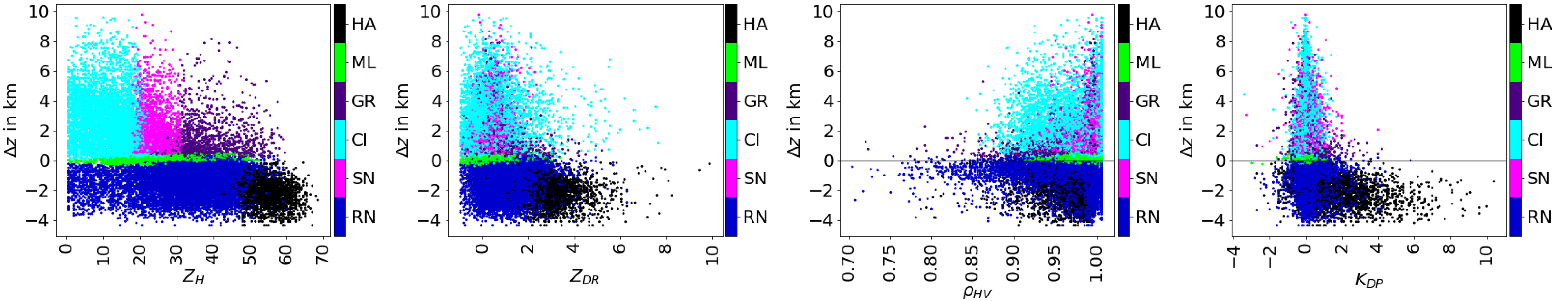
AHC of X-band Composite

Startiform

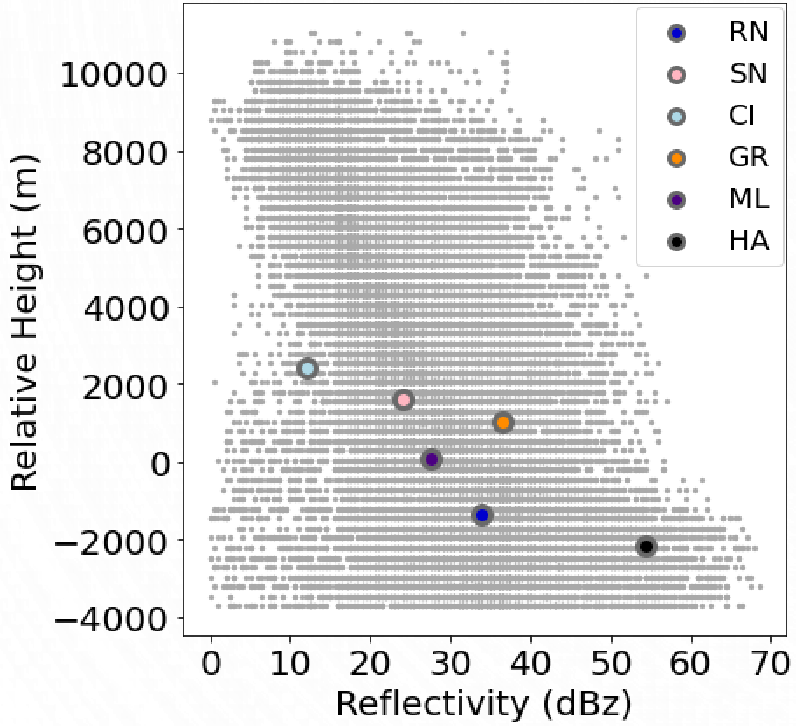


$$X_c = [\overline{Z_H}, \overline{Z_{DR}}, \overline{K_{DP}}, \overline{\rho_{HV}}, \overline{I}(T)]$$

Convective



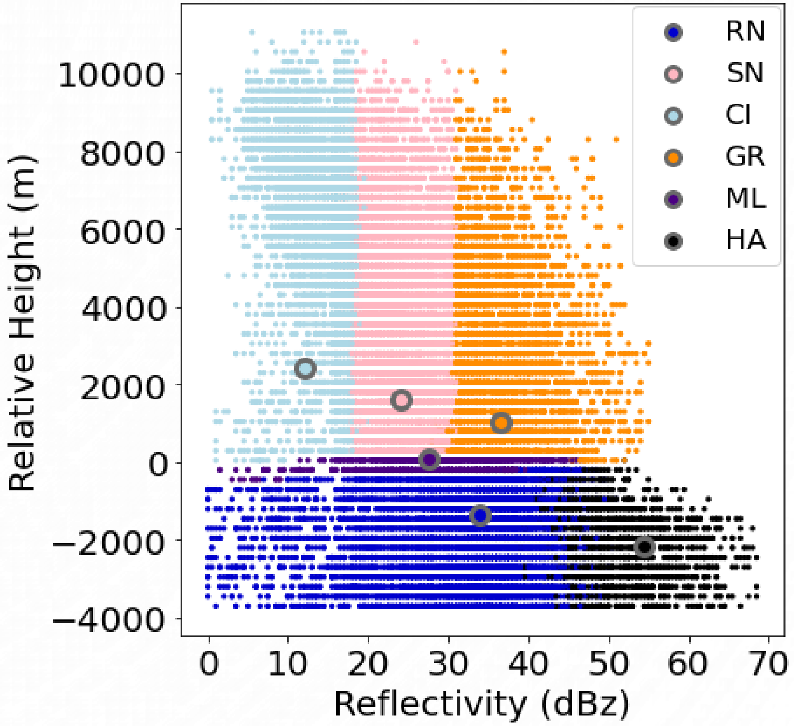
AHC of X-band Composite



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

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

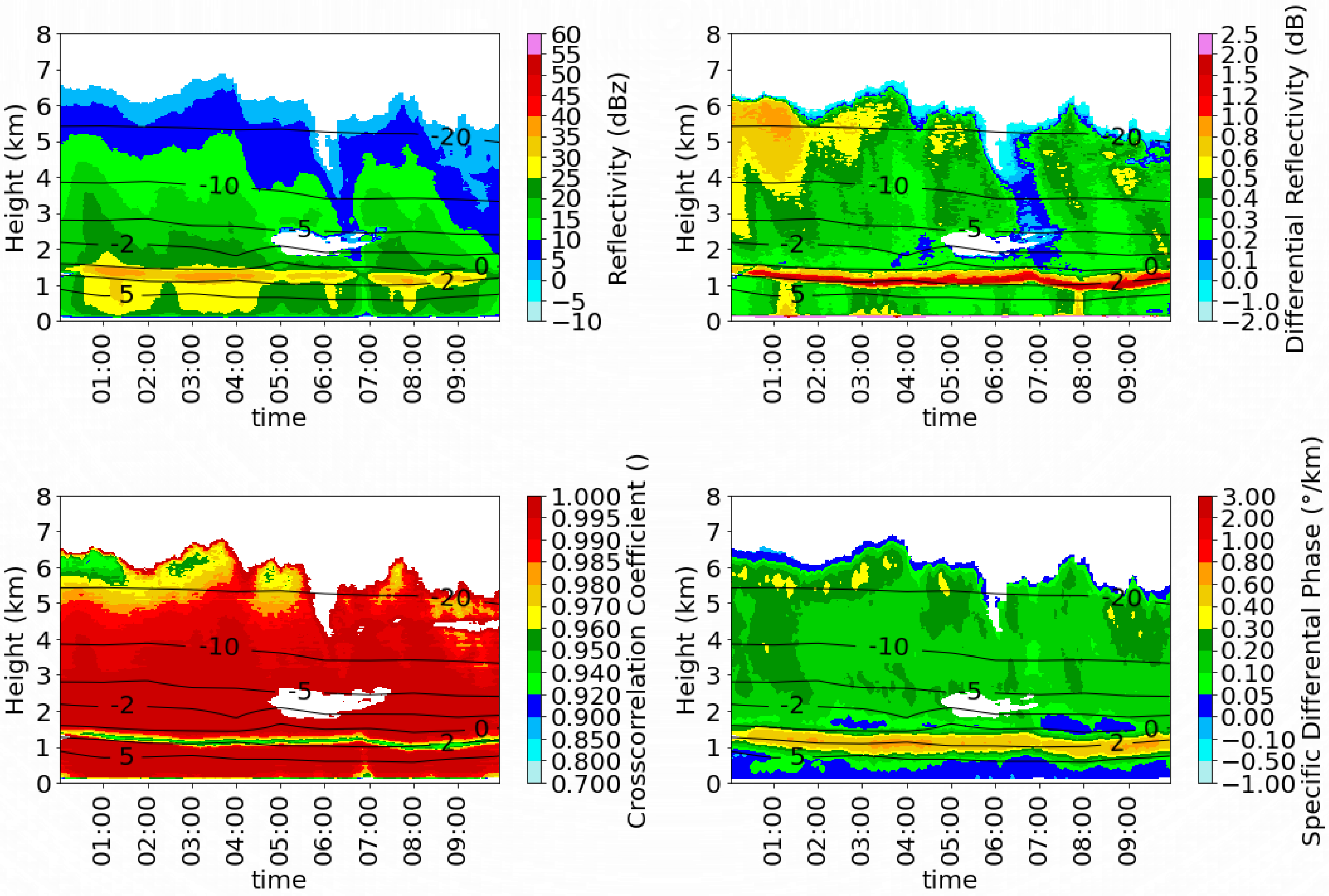
$$d_i = \|\boldsymbol{X}_c - \boldsymbol{X}_{obs}\|_2$$



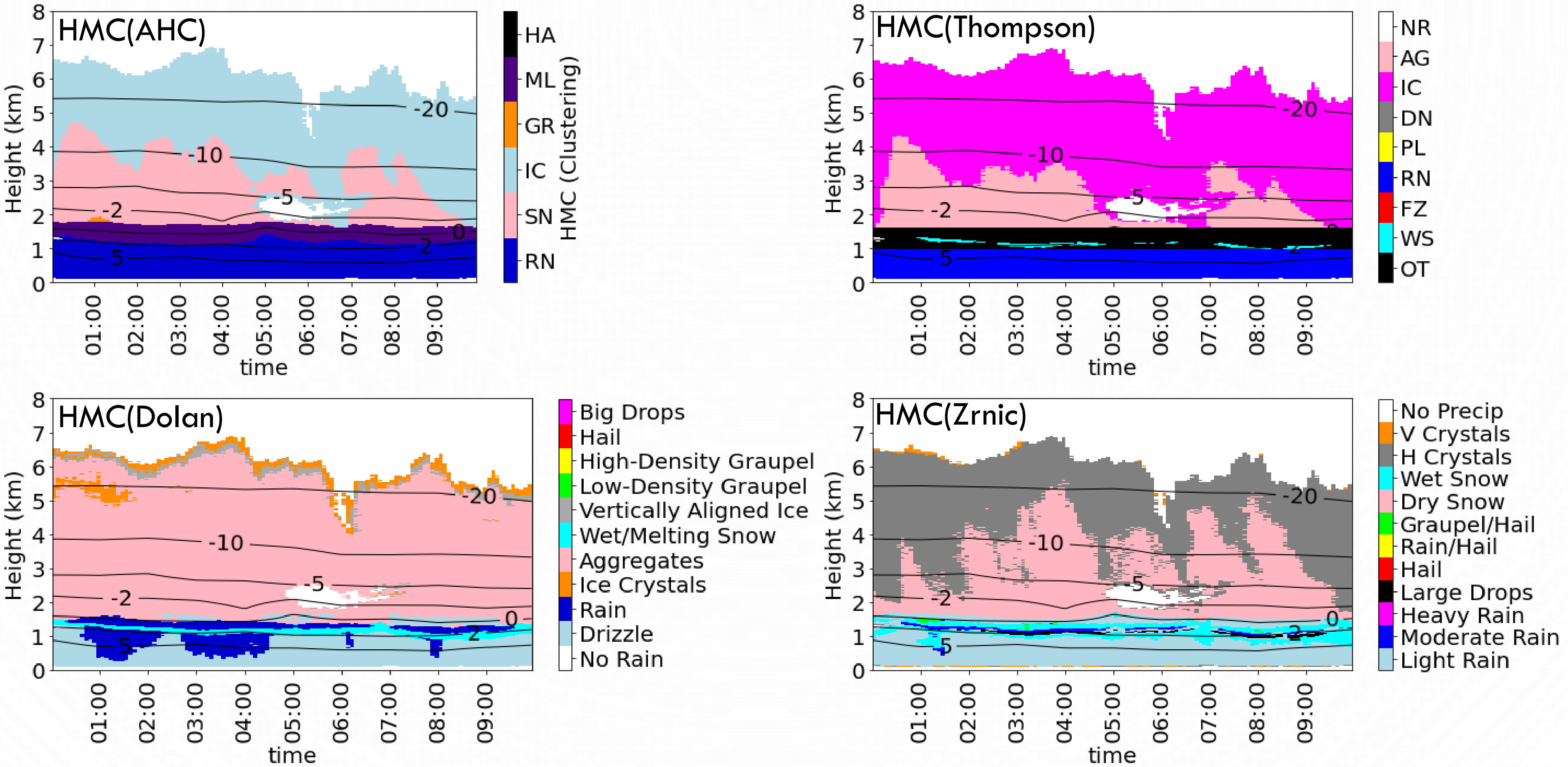
Example for clustering based HMC

QVP (X-Band)

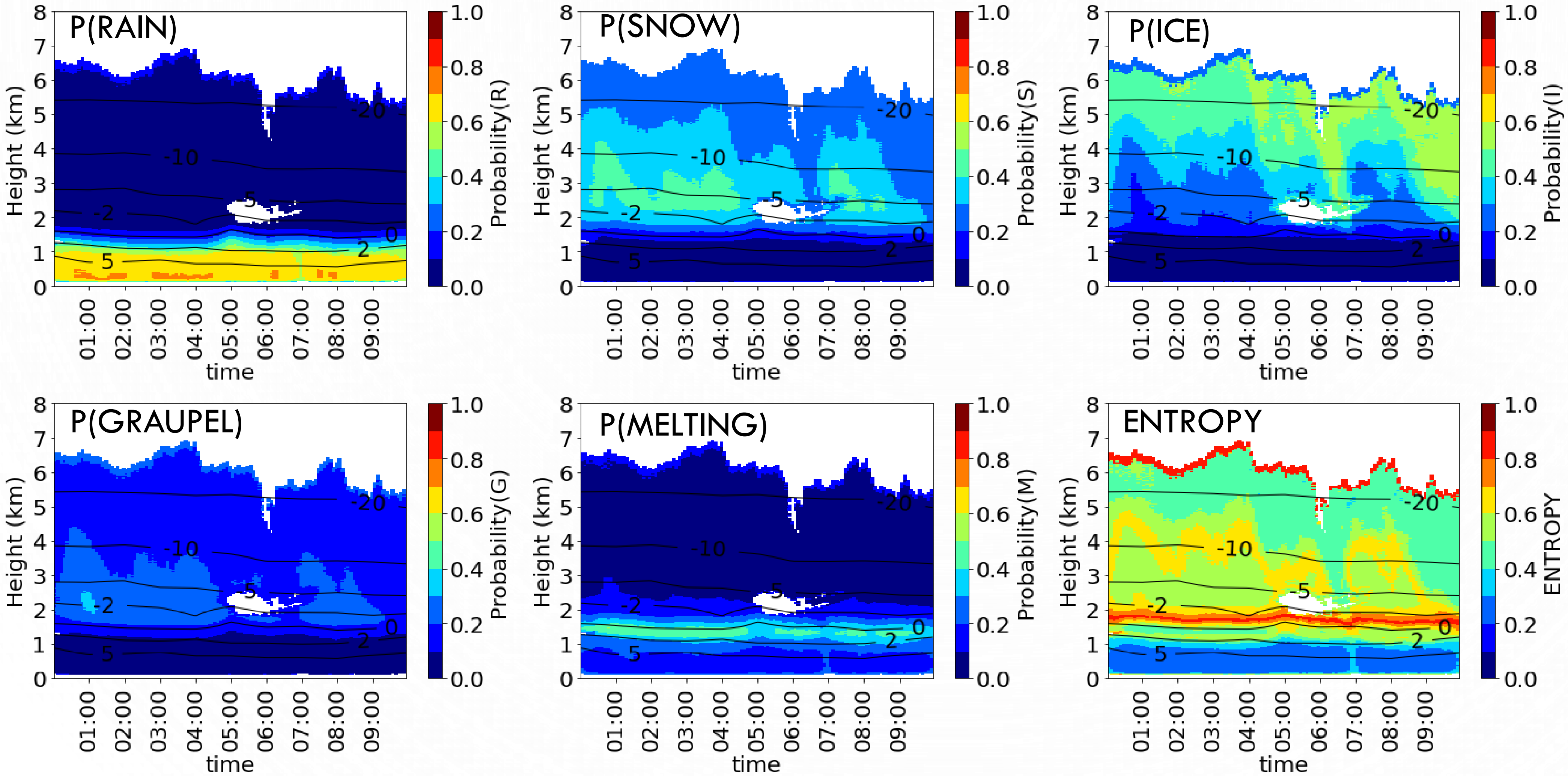
16 Nov 2014



Example for clustering based HMC



On the way to Hydrometeormixtures



$$d_i = \|\boldsymbol{X}_c - \boldsymbol{X}_{obs}\|_2$$

$$p_i = 3\exp(-3d_i).$$

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

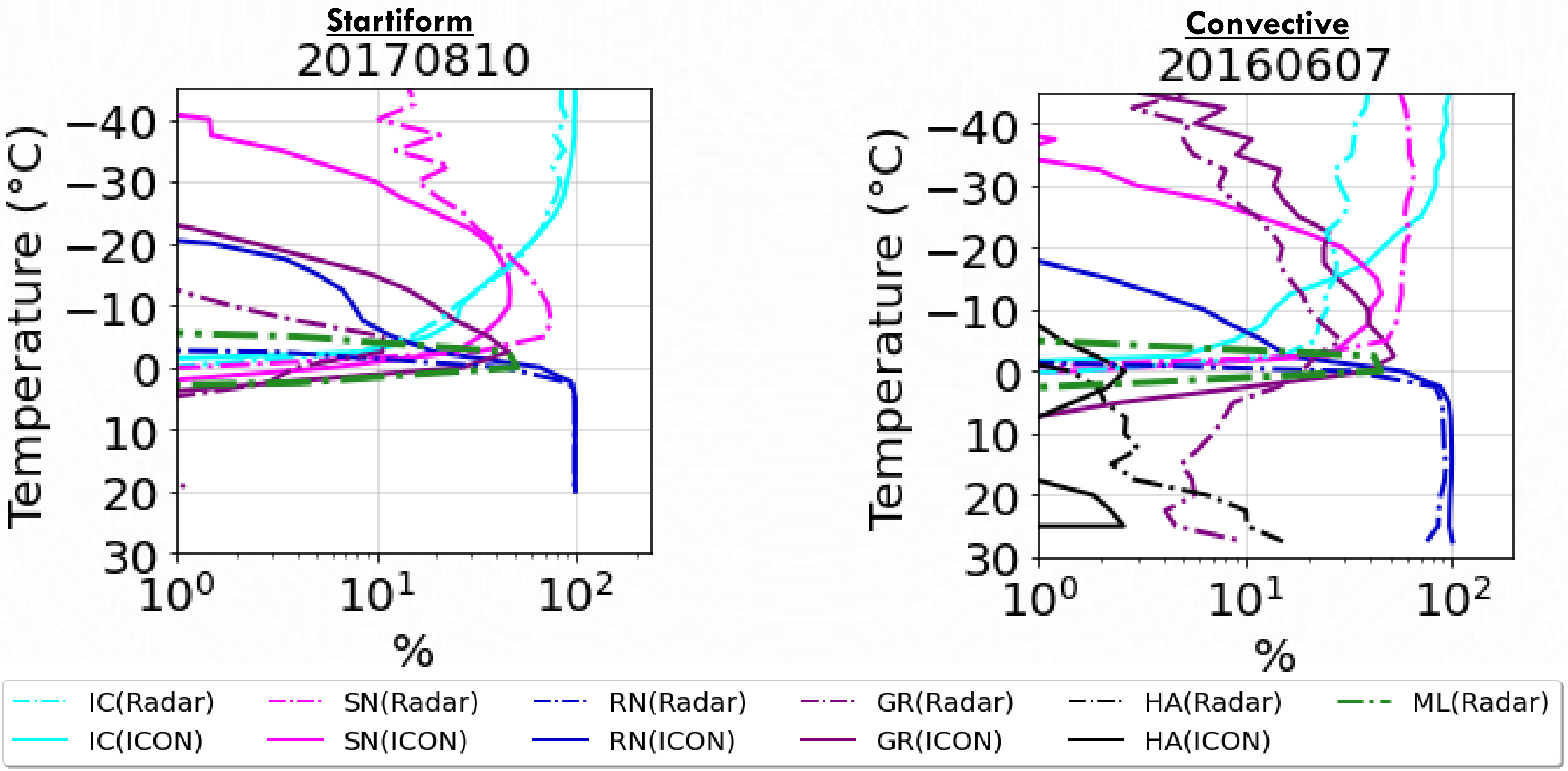
Entropy

$$H = -\sum_{i=1}^{n} p_i \log_n p_i$$

(Besic et al. 2018)

Preliminary Comparison [ICON vs RADAR]

*Relative number of counts with dominant HM (**mass** concentration)*



Thank you for your attention!

Outlook:

- *Comparison observed and synthetic PolVars*
- *HMC on synthetic and observed PolVars*
- *Comparison of model and radar hydrometeor mixtures* (Besic et al. 2018).

References:

Zrnic, D. S., A. V. Ryzhkov, J. M. Straka, Y. Liu, and J. Vivekanandan, 2001: Testing a procedure for the automatic classification of hydrometeor types. J. Atmos. Oceanic Technol., 18, 892–913.

Dolan, B., and S. A. Rutledge, 2009: A theory-based hydrometeor identification algorithm for X-band polarimetric radars. J. Atmos. Oceanic Technol., 26, 2071–2088.

Thompson, E.J., S.A. Rutledge, B. Dolan, V. Chandrasekar, and B.L. Cheong, 2014: A Dual-Polarization Radar Hydrometeor Classification Algorithm for Winter Precipitation. J. Atmos. Oceanic Technol., 31, 1457–1481, DOI: 10.1175/JTECH-D-13-00119.1

Evaristo, R., 2009: Microphysique et dynamique des systèmes précipitants en Afrique de l'Ouest. PhD Dissertation, University of Versailles.

Grazioli, J., D. Tuia, and A. Bern, 2015: Hydrometeor classification from polarimetric radar measurements: a clustering approach. Atmos. Meas. Tech., 8, 149–170, doi:10.5194/amt-8-149-2015.

Park, H. S., A. V. Ryzhkov, D. S. Zrnic, and K.-E. Kim, 2009: The hydrometeor classification algorithmfor the polarimetric WSR-88D: Description and application to an MCS. Wea. Forecasting, 24, 730–748, doi:10.1175/2008WAF2222205.1.

Tyynelä, J.,J. Leinonen, D. Moisseev, and T. Nousiainen, 2011: Radar Backscattering from Snowflakes: Comparison of Fractal, Aggregate, and Soft Spheroid Models. J. Atmos. Oceanic Technol., 28, 1365–1372, DOI: 10.1175/JTECH-D-11-00004.1

Lukach, M. and Dufton, D. and Crosier, J. and Hampton, J. M. and Bennett, L. and Neely III, R. R, 2020: Hydrometeor classi-fication of quasi-vertical profiles of polarimetric radar mea-surements using a top-down iterative hierarchical clusteringmethod – Atmospheric Measurement Techniques Discussions2020, 1–33, DOI: 10.5194/amt-2020-143

Ribaud, J.-F. and Machado, L. A. T. and Biscaro, T., 2016: Evalua-tion and application of hydrometeor classification algorithmoutputs inferred from multi-frequency dual-polarimetric radarobservations collected during HyMeX – Quarterly Journal ofthe Royal Meteorological Society142, 95–107. DOI: 10.5194/amt-12-811-2019

Besic, N. and Figueras i Ventura, J. and Grazioli, J. and Gabella, M. and Germann, U. and Berne, A., 2016: Hydrom-eteor classification through statistical clustering of polari-metric radar measurements: a semi-supervised approach –Atmospheric Measurement Techniques9, 4425–4445, DOI:10.5194/amt-9-4425-2016.

Besic, N. and Gehring, J. and Praz, C. and Figueras i Ventura, J. and Grazioli, J. and Gabella, M. and Germann, U. and Berne, A. ,2018: Unraveling hydrometeor mixtures in polarimetric radarmeasurements – Atmospheric Measurement Techniques11,4847–4866, DOI: 10.5194/amt-11-4847-2018