A new aggregation and riming discrimination algorithm based on polarimetric weather radars

UNIVERSITÄT BONN | institut für geowissenschaften METEOROLOGIE | DFG

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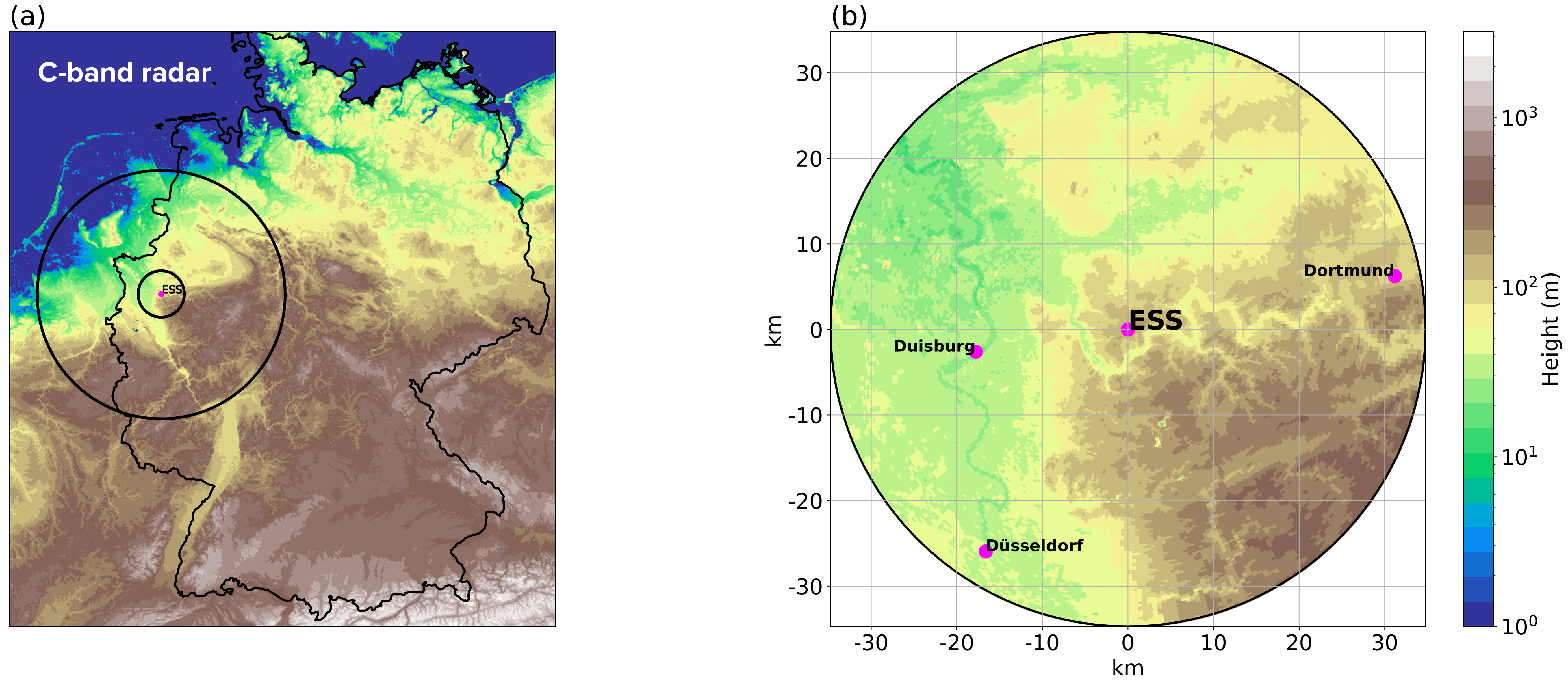
MOTIVATION

The need for an area wide algorithm for riming detection purely based on slant-viewing polarimetric radars.

OUTLINE

1. Create QVPs of Z_H, Z_{DR} and depolarization ratio DR — 12°
2. Ground truth: MDV from processed and corrected Doppler Spectra
3. Testing various machine learning methods
4. Finding best performing algorithm
5. Evaluation on independent test case

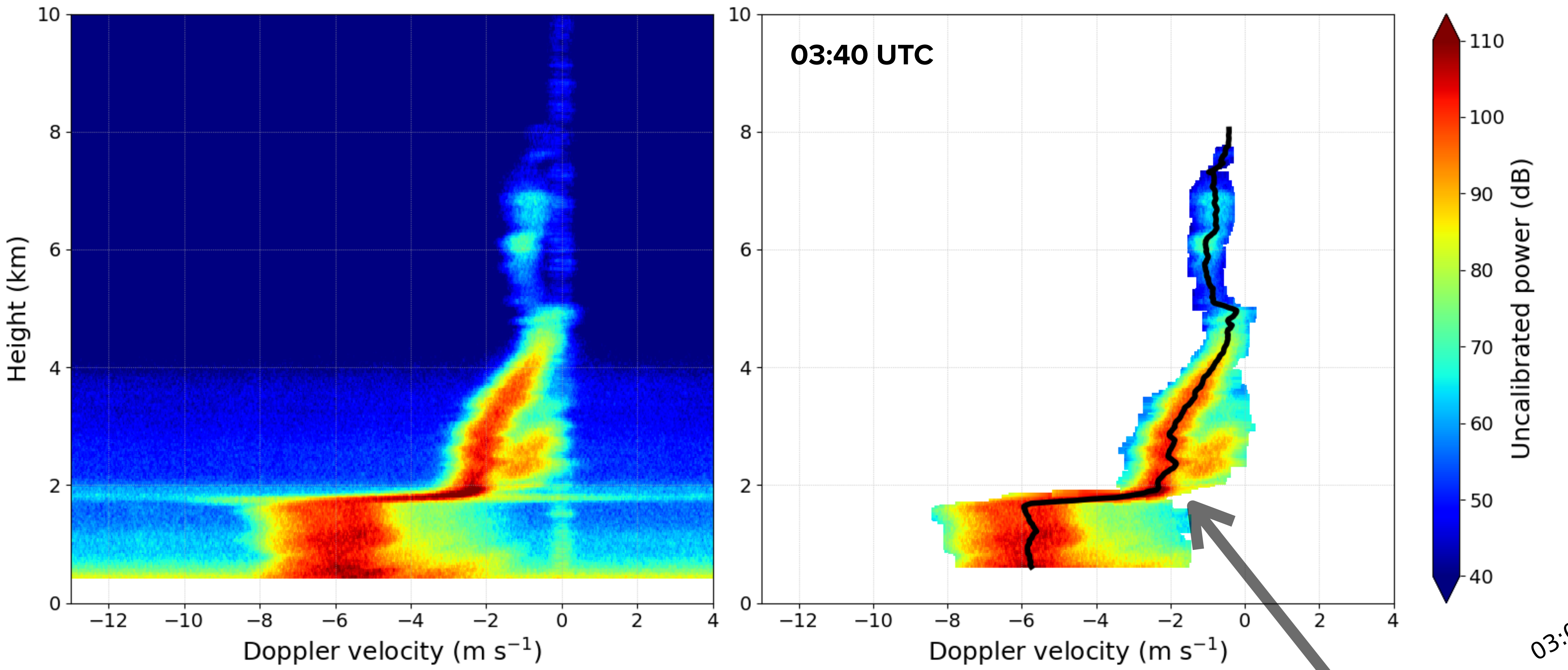


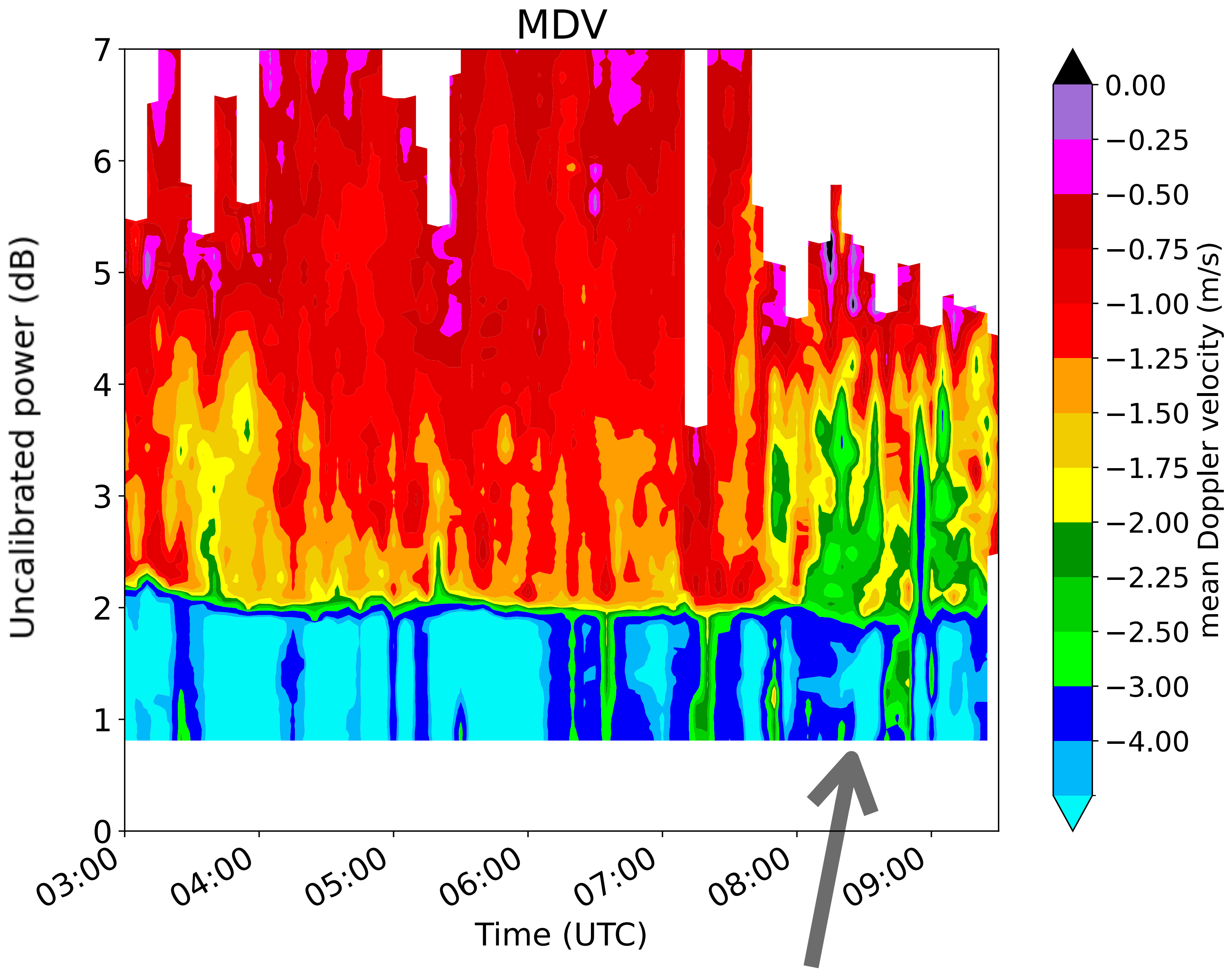
Is DR alone sufficient to detect riming?

$$\mathrm{DR} = 10\log_{10}\left[\frac{1 + Z_{dr} - 2\rho_{hv} Z_{dr}^{1/2}}{1 + Z_{dr} + 2\rho_{hv} Z_{dr}^{1/2}}\right]$$

- DR is a good proxy for radar circular depolarization ratios
- presented as potential candidate for riming detection (Ryzhkov et al., 2017)
- Similar to Z_{DR}, DR is lower in rimed snow than in aggregated snow
- Difference in DR is larger (2-4 dB) than for Z_{DR} (0.2-0.4 dB)

Mean Isolated Spectra Profile (MISP)





Riming: MDV > 1.5 m/s

2 January, 2022 recorded by ESS

1. **Apply postprocessing algorithm to isolated weather signal following Gergely et al. (2022) and calculate mean profiles for every 5 min**

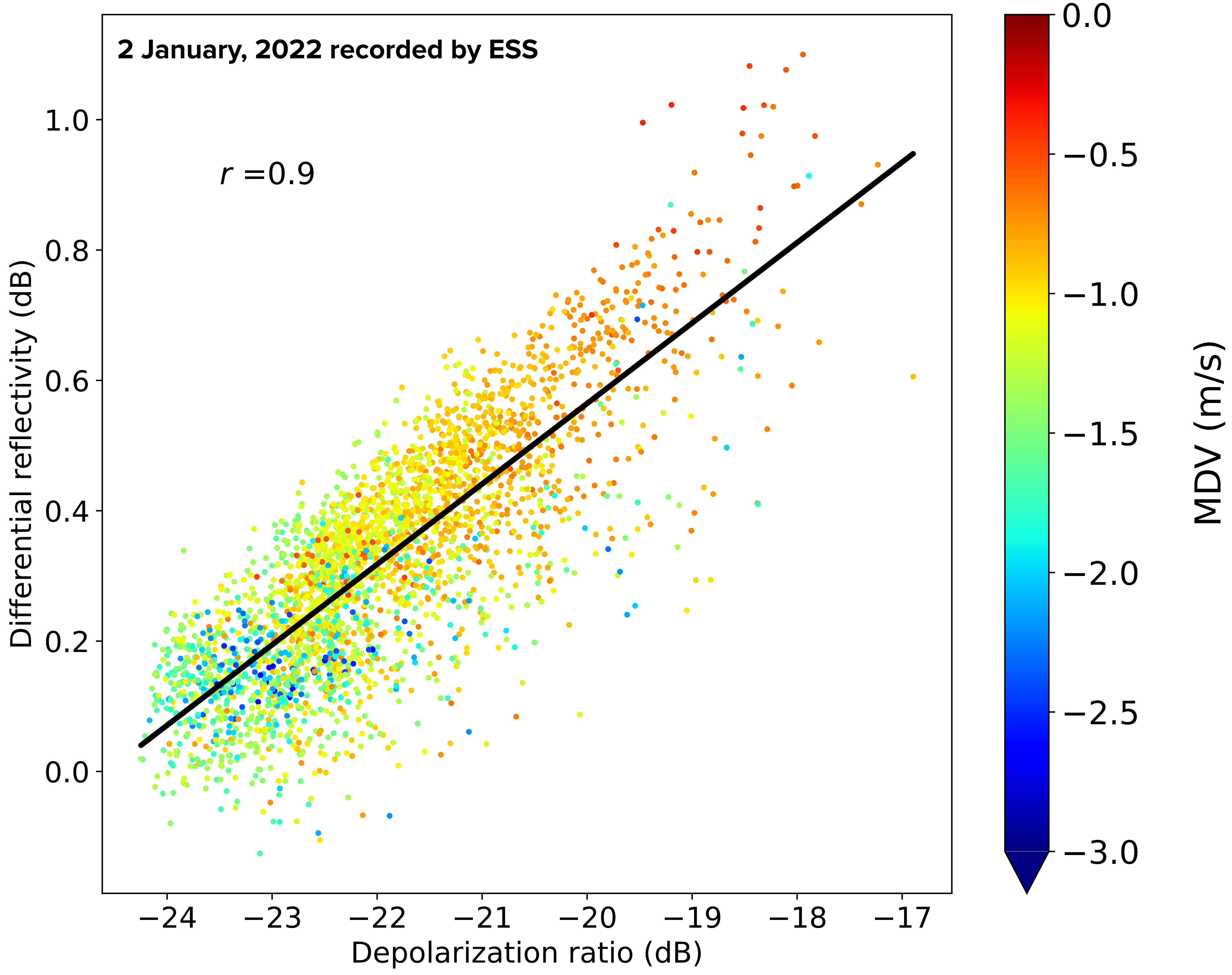
2. **Creation of MISP time series of MDV**
Convenient time vs. height format allowing direct comparisons to QVPs

3. **Air density transformation following Heymsfield et al. (2013) :**

$$\mathrm{MDV}(z) = \mathrm{MDV_r}(z)\left[\frac{p(z)}{p_{ref}}\right]^{0.4}$$

4. **Derive rime mass fraction (RMF) following Kneifel and Moisseev (2020) from MISP of MDV**

Is DR a potential candidate for riming detection?



Correlation between MDV and DR is 0.7

→ shows strong potential

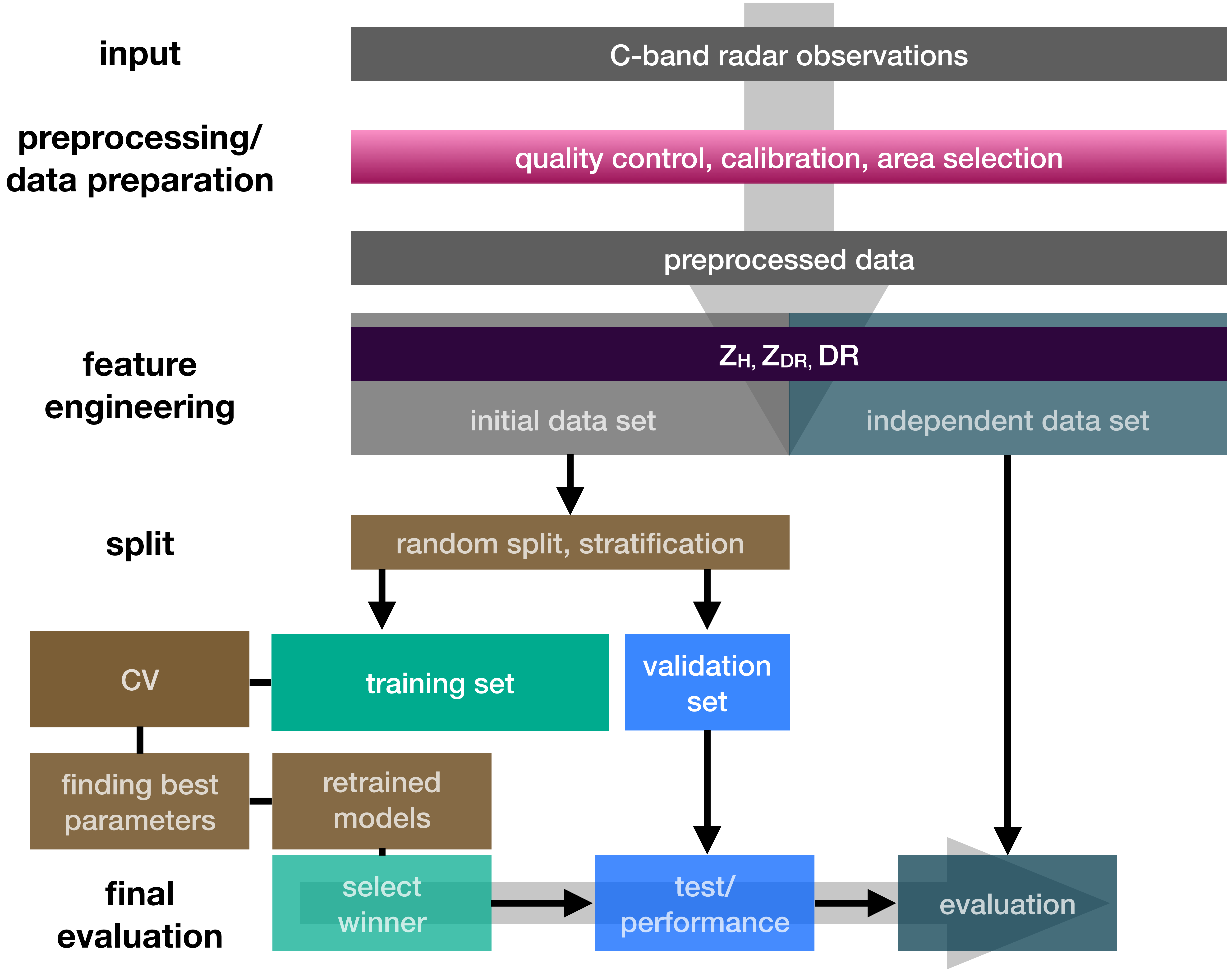
→ extend to more cases

But is DR sufficient as a predictor?

→ investigate other predictors and their combinations

→ automatic procedure for finding meaningful patterns

Workflow



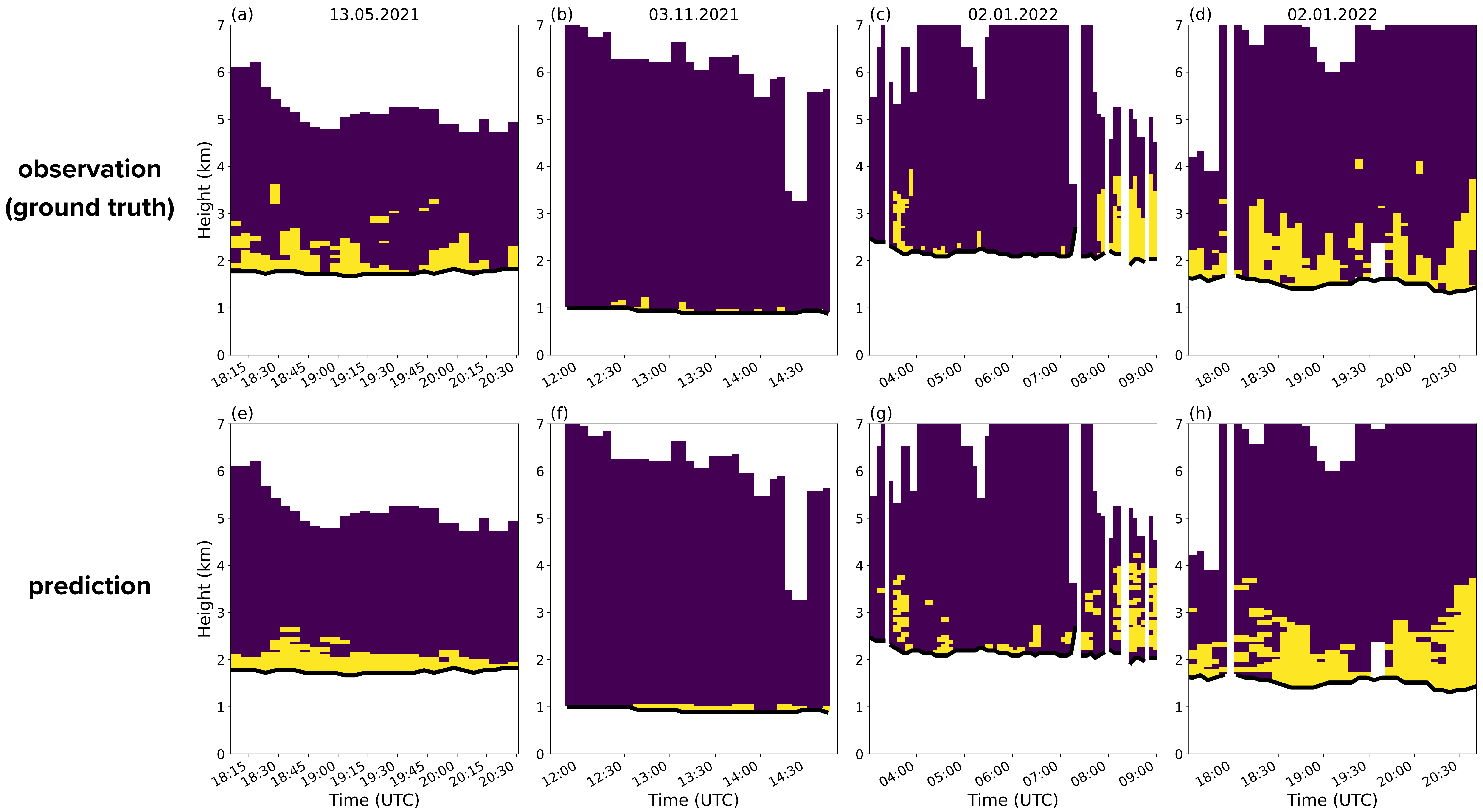
General specifications

- Initial data set: 5 cases
- Training: 70% Hold-out: 30%
- Riming: 21% No Riming: 79%
- *scikit-learn* Python machine learning library (Pedregosa et al., 2011)

Overview of classification techniques:

Classifier	Abbreviation
threshold-based approach	TB
logistic regression	LR
quadratic discriminant analysis	QDA
gradient boosting machine	GBM
artificial neural network	ANN

Results: initial data set



convert to binary fields:

Performance measures

Classifier	ACC	BA	F1 score	MCC	NMCC	J	κ
TB	0.77	0.58	0.32	0.2	0.6	0.19	0.19
LR	0.8	0.58	0.29	0.27	0.64	0.17	0.21
QDA	0.81	0.59	0.32	0.34	0.67	0.19	0.26
GBM	**0.84**	**0.68**	**0.52**	**0.47**	**0.73**	**0.36**	**0.44**
ANN	0.82	0.65	0.46	0.38	0.69	0.3	0.36

→ **winner: fine-tuned gradient boosting model**

Results: independent data set

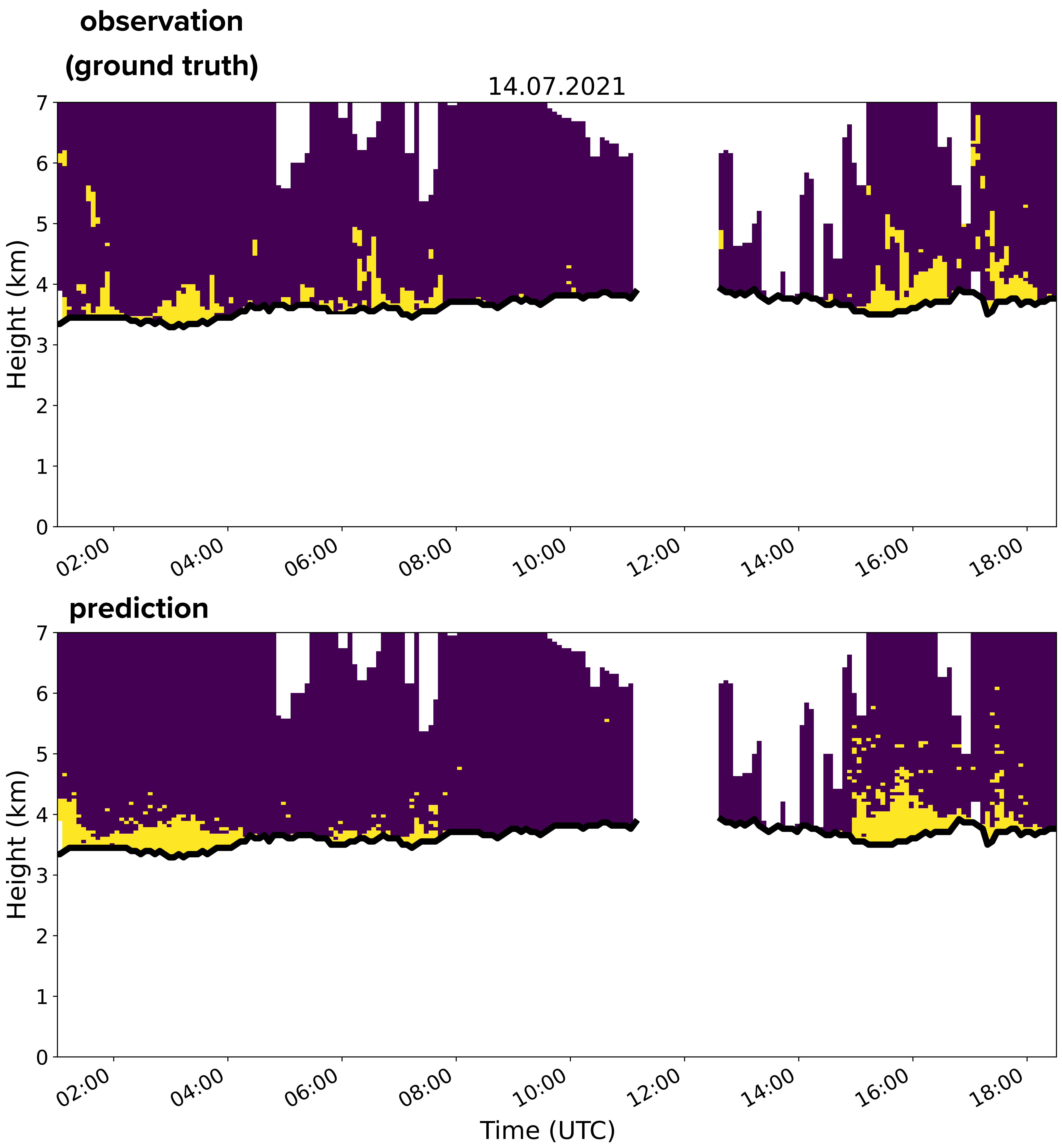
Evaluation on Ahr flooding event in western Germany 2021

Classifier	ACC	BA	F1 score	MCC	NMCC	J	κ
	Performance measure						
GBM	**0.94**	0.74	**0.51**	**0.47**	**0.74**	**0.34**	**0.47**

Shapley values (Shapley et al. 1953) & decompositions

Predictor	Independent ψ	Initial ψ
Z_H	0.36 (49 %)	0.31 (40.5 %)
Z_{DR}	0.18 (24 %)	0.21 (28.5 %)
DR	0.20 (27 %)	0.24 (31 %)

- Mean Z_H: 21.48 dBZ
- Mean Z_{DR}: 0.3 dB
- Mean DR: -21.21 dB
- Mean MDV: -1.45 m/s
- Mean RMF: 0.43



CONCLUSIONS

- Successfully developed an area wide riming algorithm based on slant-viewing polarimetric radars only (WP-6)

- Widely used binary scores demonstrate that the best performing GBM algorithm performs well and is able to correctly predict 74% (BA) of observed riming features

- With the help of Shapley values it was shown that DR provides a crucial contribution towards the algorithm development

Questions, suggestions?

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