PrePEP - Conference: Precipitation Processes - Estimation and Prediction
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University of Bonn

Rainfall Estimation for Winter Events with Polarimetric VPR Applied to the German Radar Network

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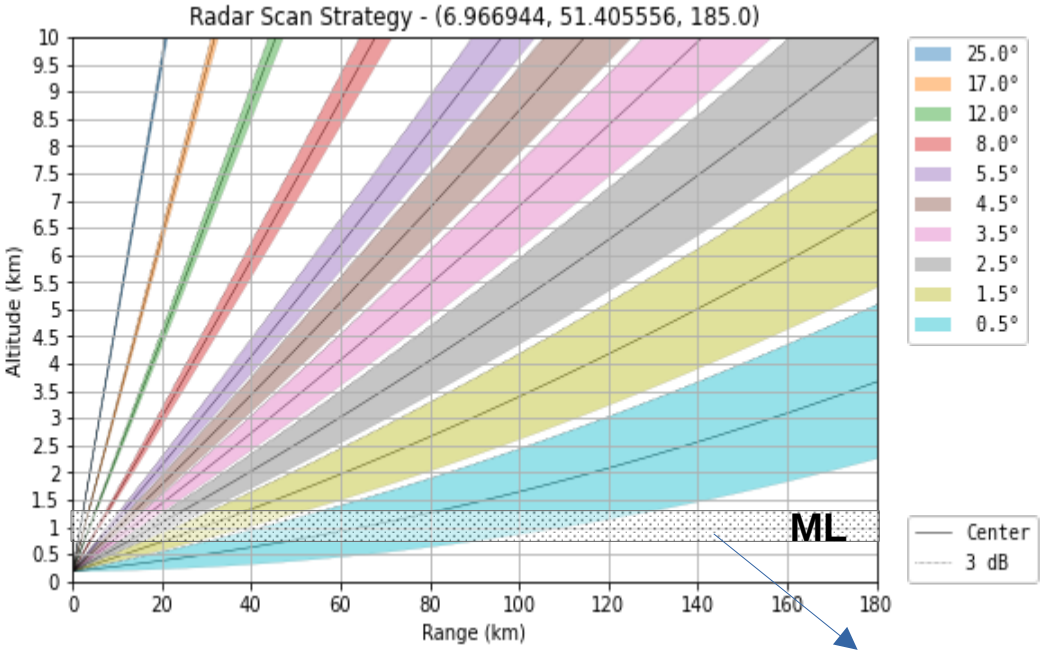
DFG

UNIVERSITÄT BONN institut für geowissenschaften

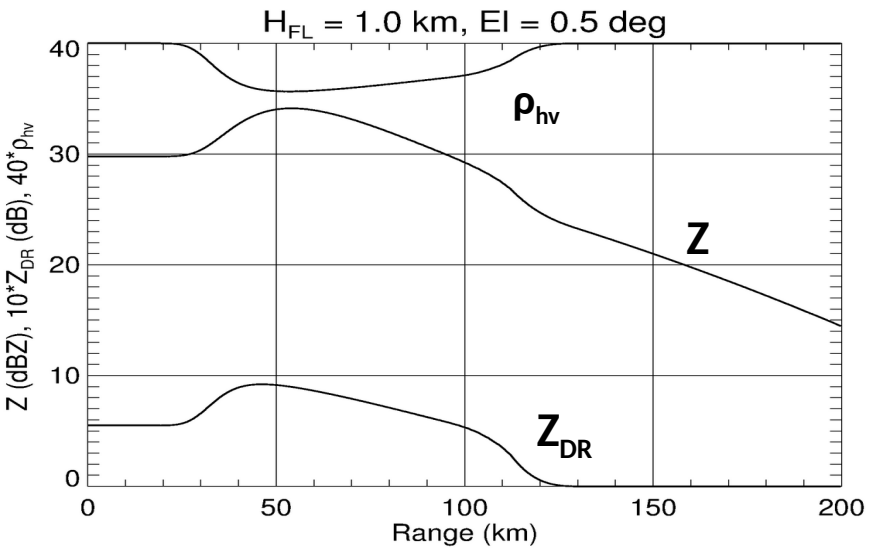
RealPEP

The problem

Vertical cross-section radar scan DWD (German Meteorological Service)



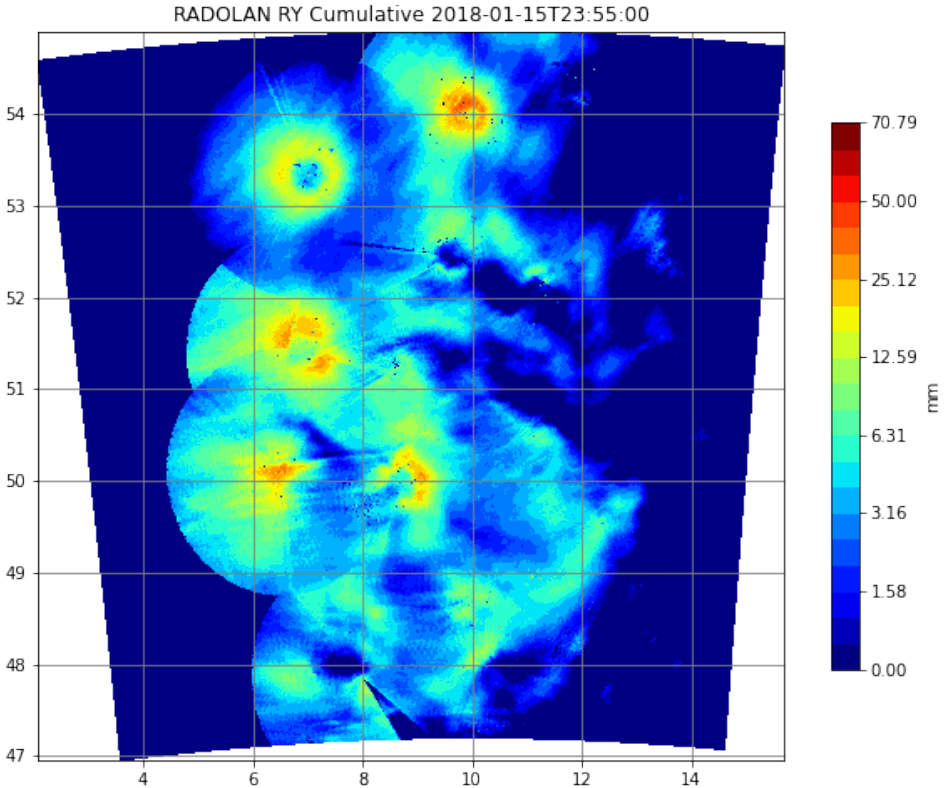
Radial profile of Z_H, Z_{DR} and ρ_{HV}



Low Melting layer

The problem

Composite Daily Rainfall over Germany

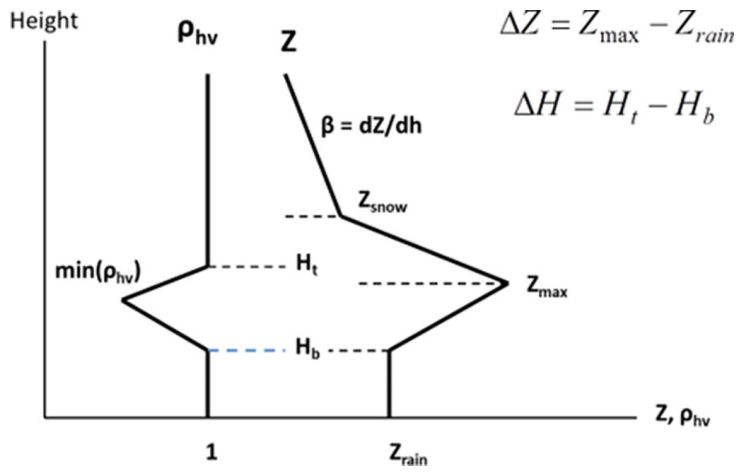


RY product

- Circles surrounding radar stations
- Lowest radar beam intercepting the ML (lower than 1 km)
- Beam overshooting the ML sampling snow results in underestimation of precipitation amount at the surface

PVPR: Polarimetric Vertical Profile Reflectivity

Idealized vertical profile of Z_H and ρ_{HV}



$$\Delta Z = Z_{\max} - Z_{rain}$$

$$\Delta H = H_t - H_b$$

Radial profiles of Z bias and ρ_{hv} are correlated. Deeper minimum of ρ_{hv} corresponds to higher Z bias and one can quantify the Z bias using radial profile of ρ_{hv}.

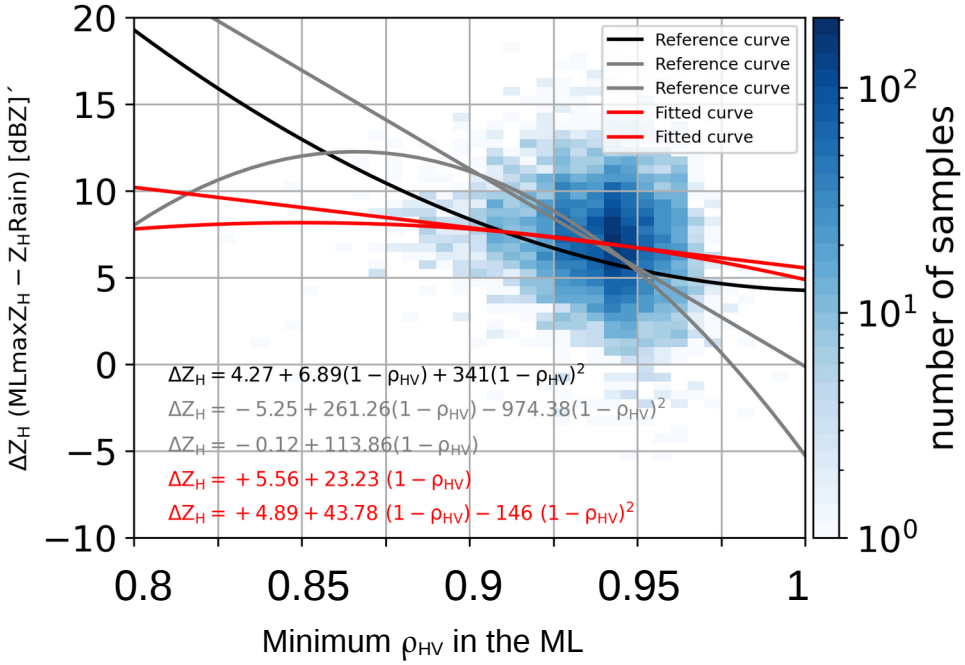
H_b = Height of ML bottom

ΔH = ML thickness

Methodology

1) Establish correlations between ΔZ and ρ_{HV} from statistical analysis of QVP

- **Adapted to C-band and German climatology using 5 years (2015-2020) with the Prötzel radar – Julian Giles, Uni Bonn (talk on Friday at 10:00)**



Methodology

1) Establish correlations between ΔZ and ρ_{HV} from statistical analysis of QVP

2) Generate several radial profiles of Z_H and ρ_{HV} for a typical stratiform cloud at low antenna elevations typically used in QPE

- For a multitude of ML heights and ML thicknesses
- Store in lookuptables

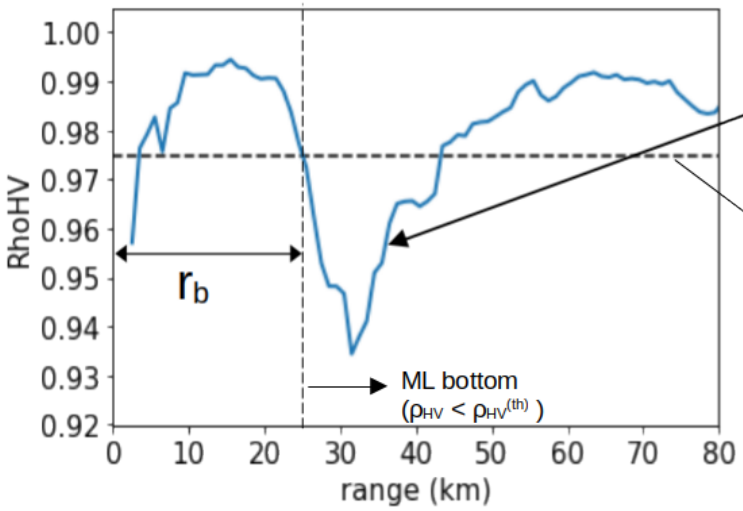
Methodology

1) Establish correlations between ΔZ and ρ_{HV} from statistical analysis of QVP

2) Generate several radial profiles of Z_H and ρ_{HV} for a typical stratiform cloud at low antenna elevations typically used in QPE

3) Characterize observed radial profiles through

- ρ_{HV} **dip in the ML and**
- **the height of the ML bottom**



$$S = \int_{r_b}^{r_t} [\rho_{hv}^{(th)} - \rho_{hv}(r)]dr$$

$\rho_{HV}^{(th)} = 0.975$

Methodology

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4) Find in the lookuptables the modeled profile that best fits the observation and use it to retrieve the intrinsic Z_H profile at the surface

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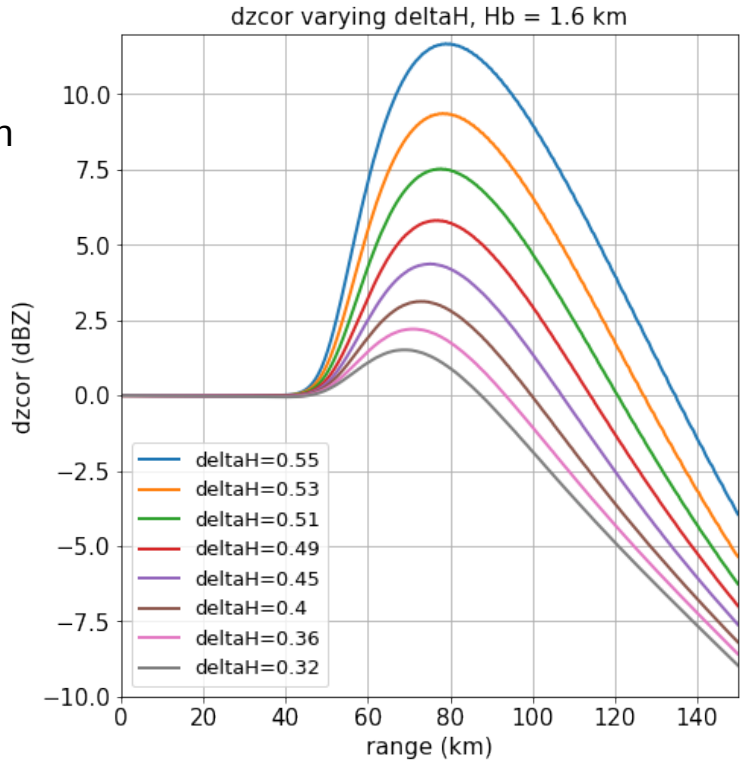
5) Use the corrected Z_H profile to calculate rain rates

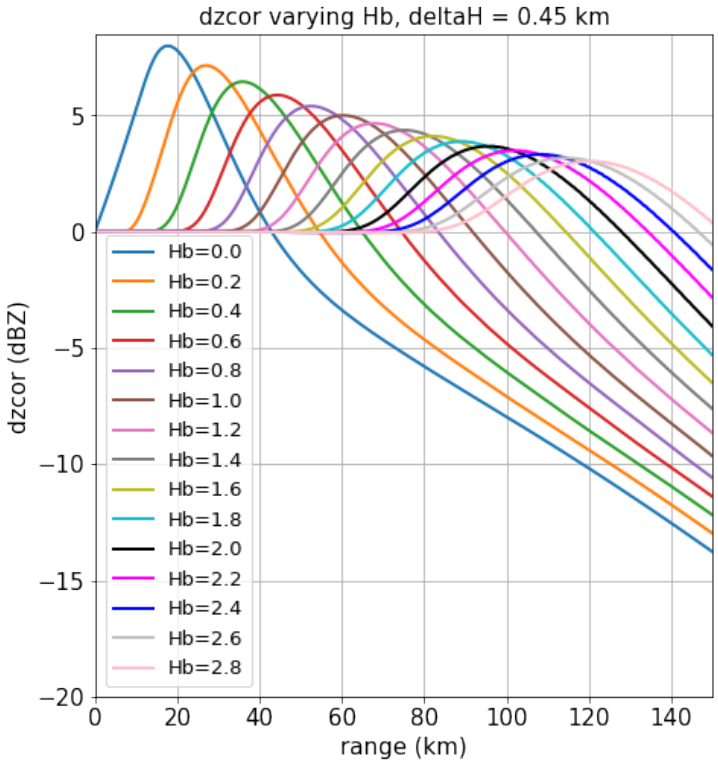
The Lookuptables

dzcor: correction applied to the Z_H profile

Varying ML thickness



Varying ML height



El = 1.0°

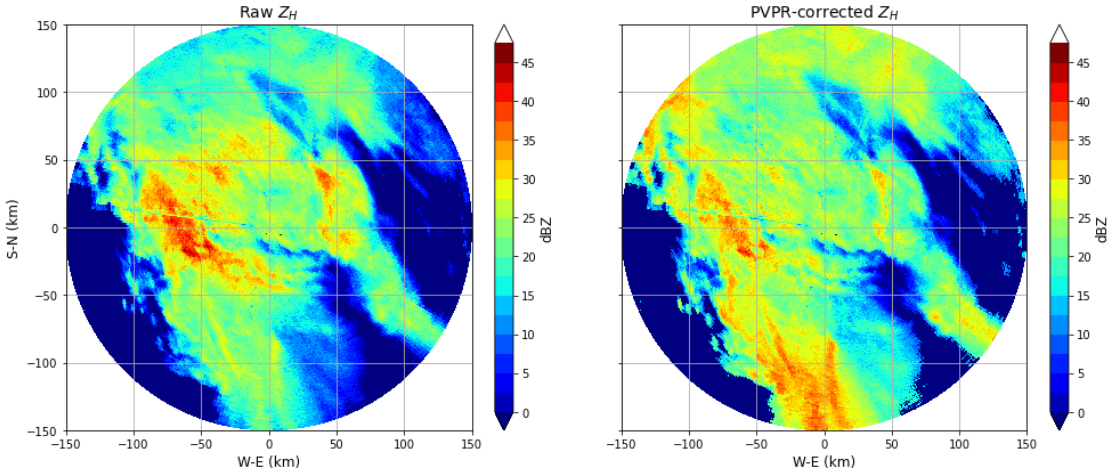
Default PVPR profile correction

Application of PVPR Method

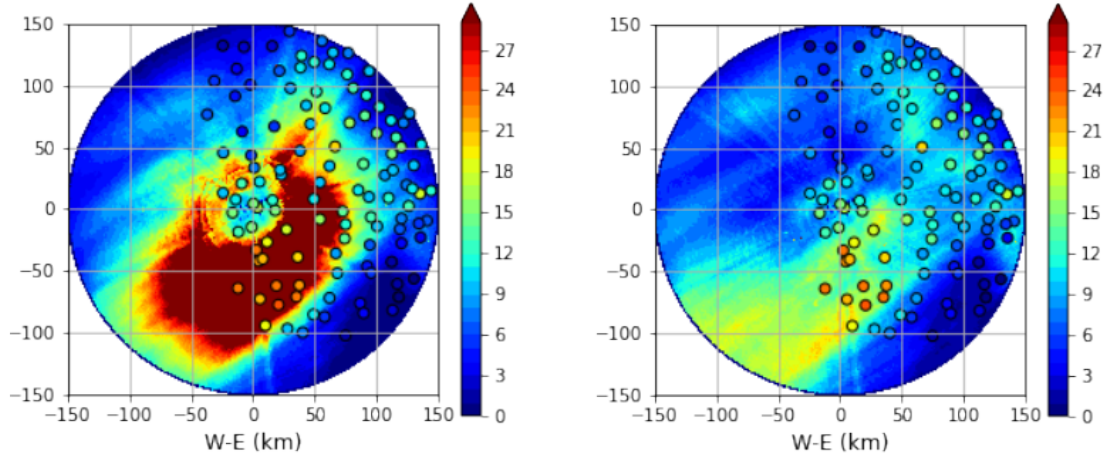
No correction

PVPR correction

PPI of ZH

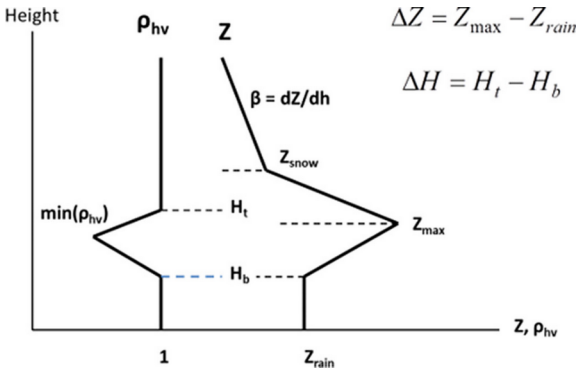


Daily rainfall



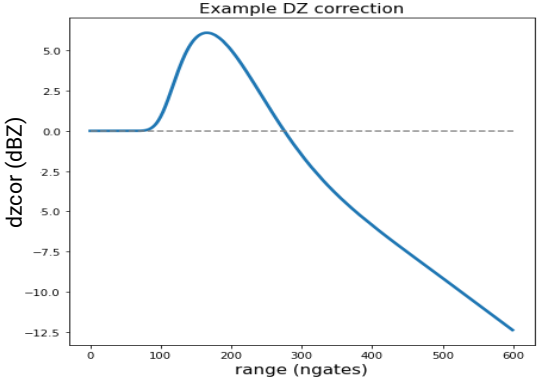
20180125 Nhb

Testing different parameters



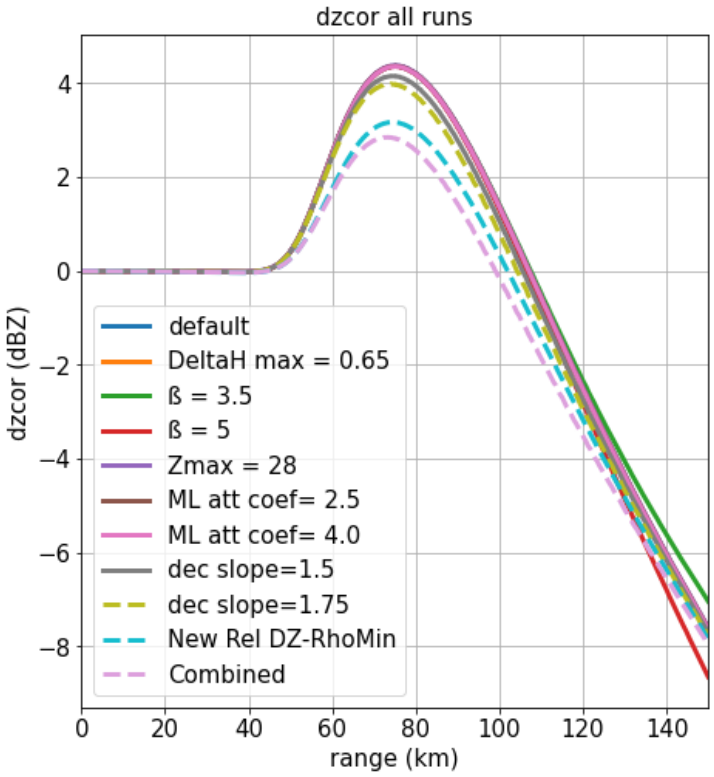
$$\Delta Z = Z_{max} - Z_{rain}$$

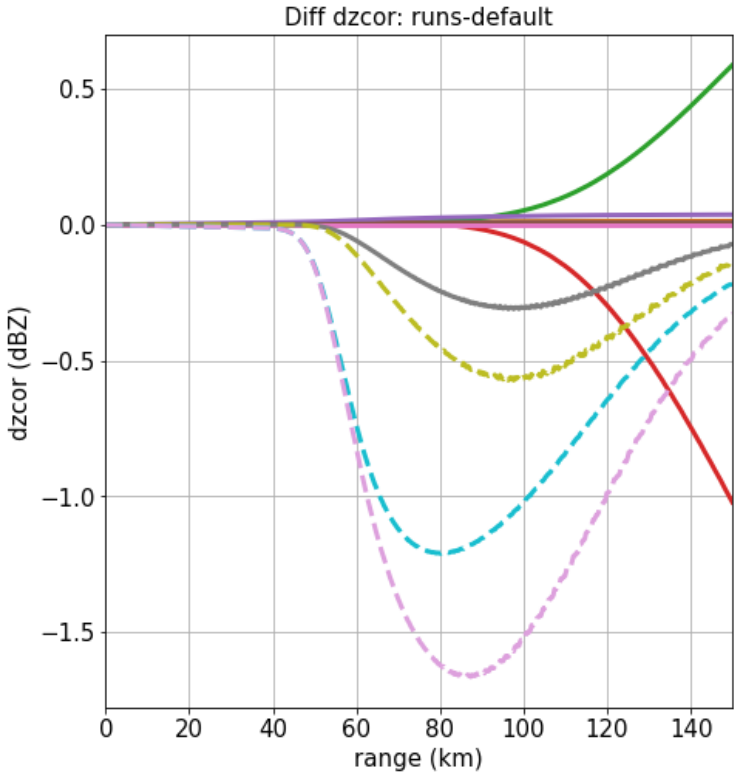
$$\Delta H = H_t - H_b$$



	Default	updates
Max ΔH (km)	0.55	0.65
β (dB/km)	4	3.5
		5
Zmax (dBZ)	30	28
Multiplicative factor to α within the ML	2.0	2.5
		3
		4
Decreasing slope after the ML peak	1.25	1.5
		1.75
Relationship min ρ_{HV} - ΔZ	USA stats	Germany
Combination of the blue colored parameters		

Testing different parameters

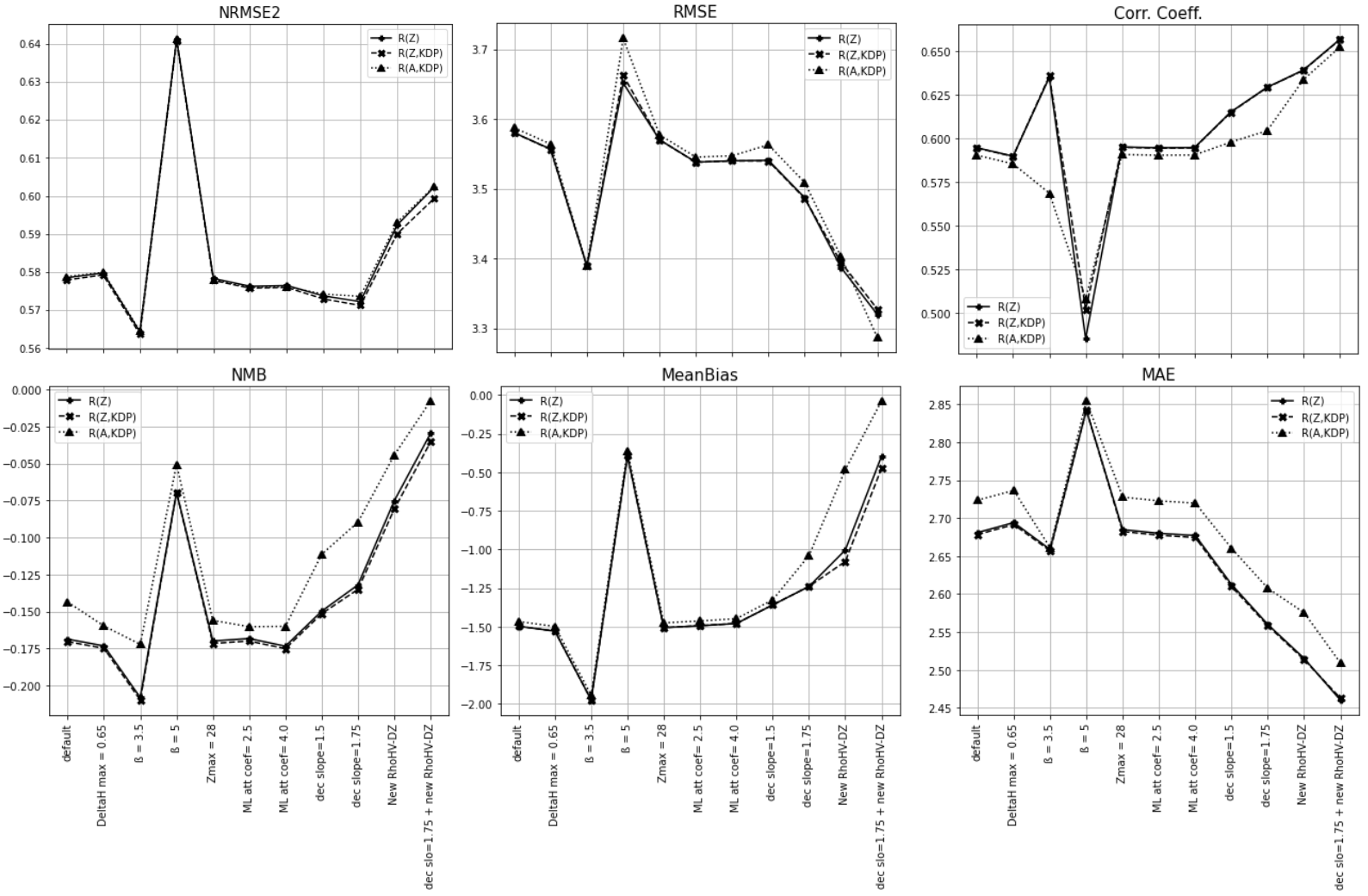




- Differences are mostly small
- Largest impact for:
  - β at far ranges
  - Decreasing slope after the ML
  - New rel. min ρ_{HV} – ΔZ
  - Combination of both

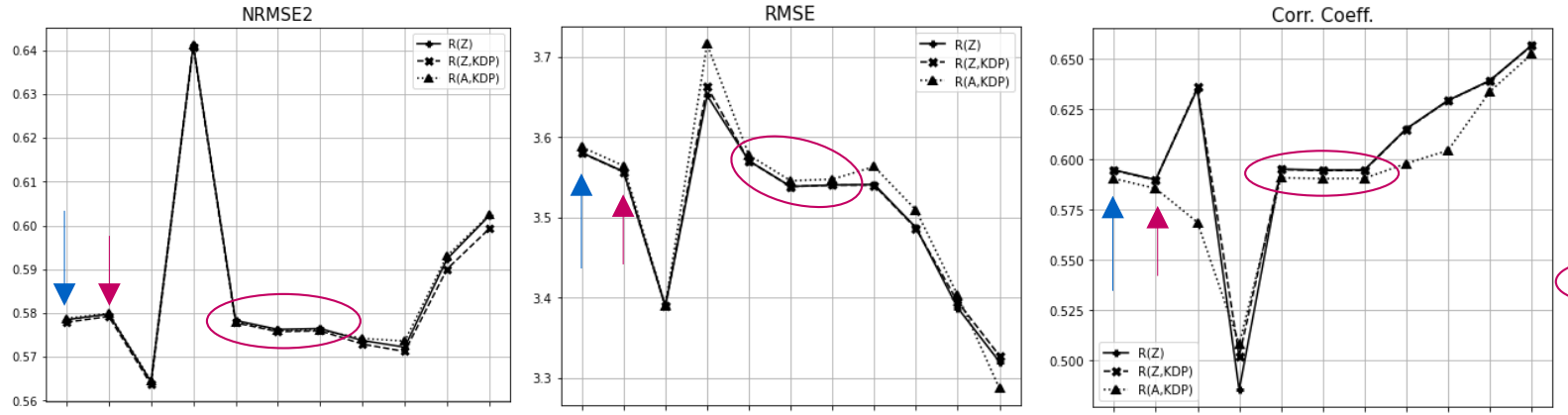
El = 1.0°, Hb = 1.6 km, ΔH = 0.45 km

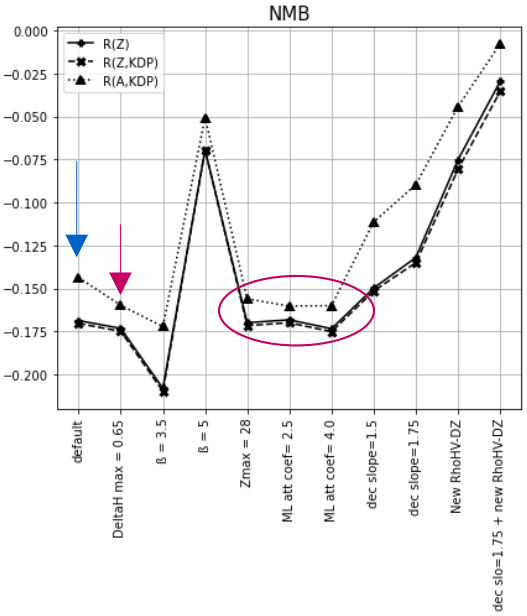
Statistics for all rain events in January 2018

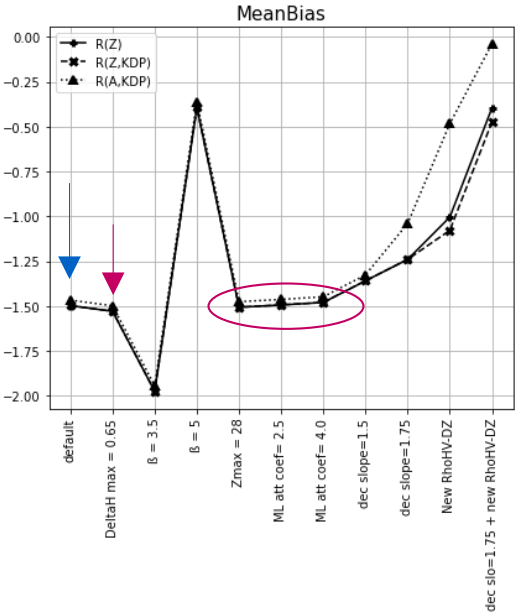


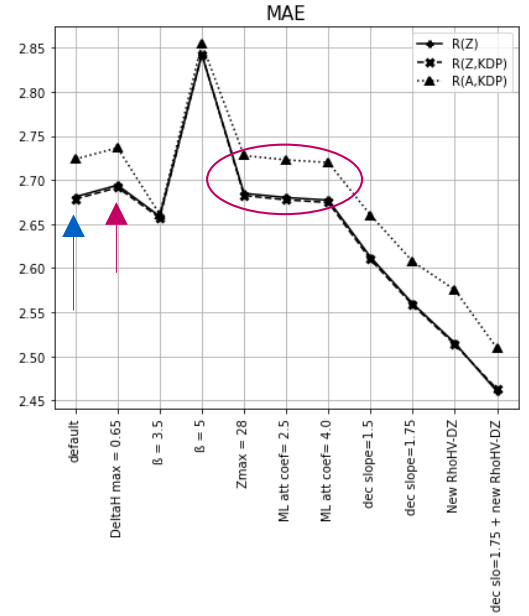
- PVPR with different parameters applied to all rain events for 1 winter month
- Validate against rain gauges

Statistics for all rain events in January 2018







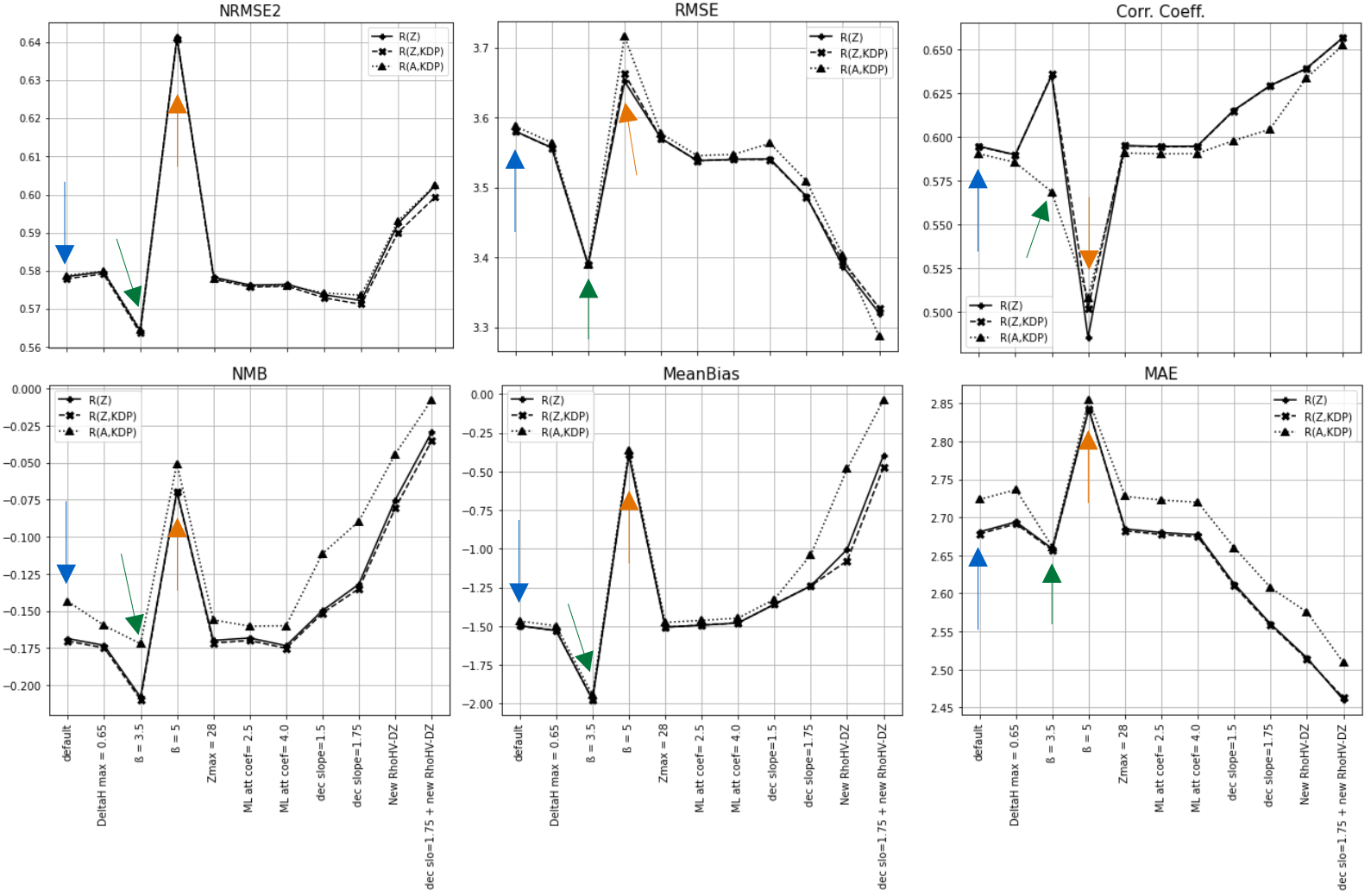


default

very small impact:

- ML thickness
- Max Zh in ML
- Coefficients ML attenuation

Statistics for all rain events in January 2018

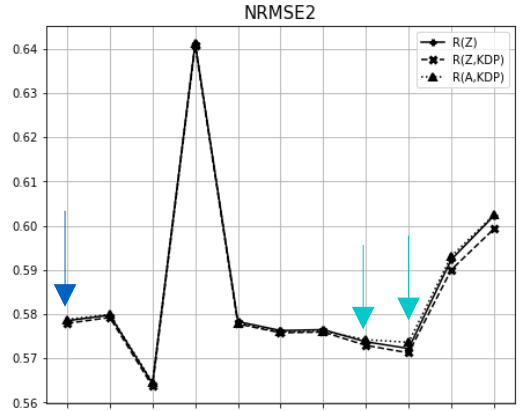


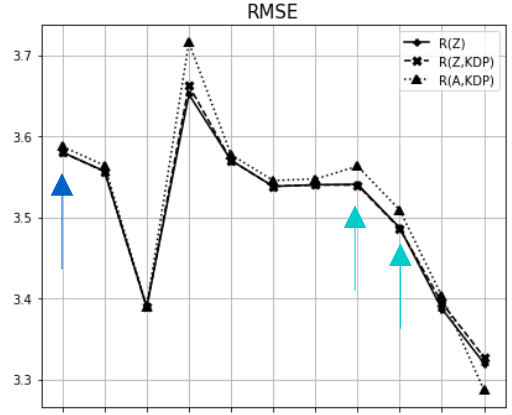
default

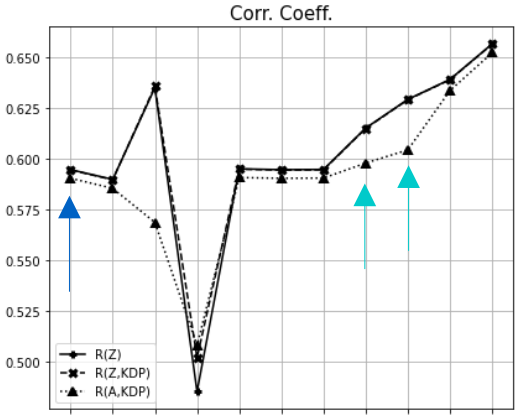
β = 3.5 dB/km
- Improves all metrics
- worsens bias

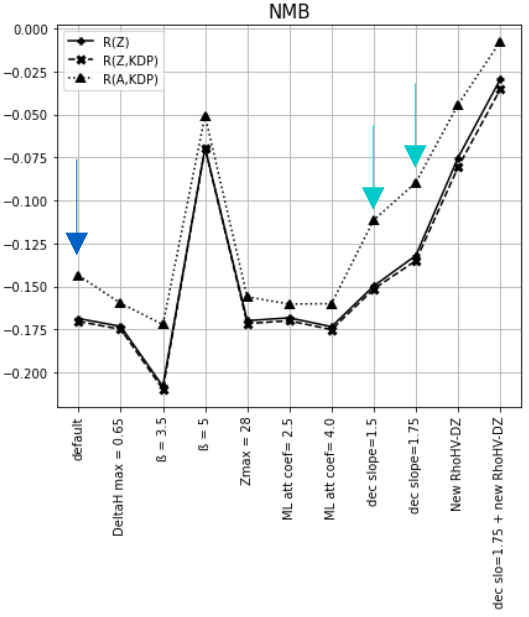
β = 5 dB/km
- Worsens all metrics
- Improves bias

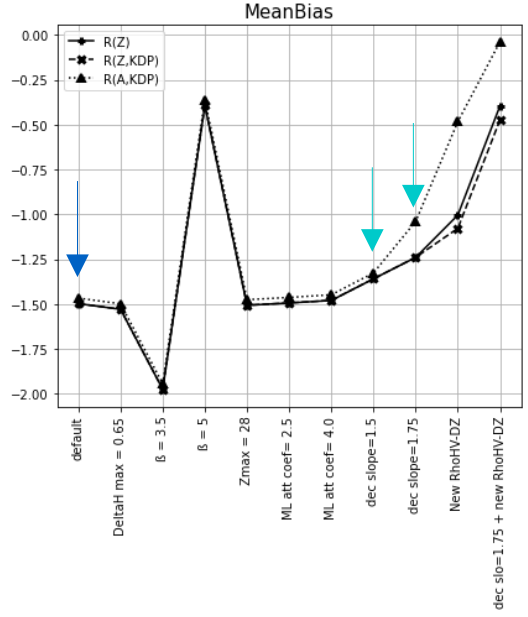
Statistics for all rain events in January 2018

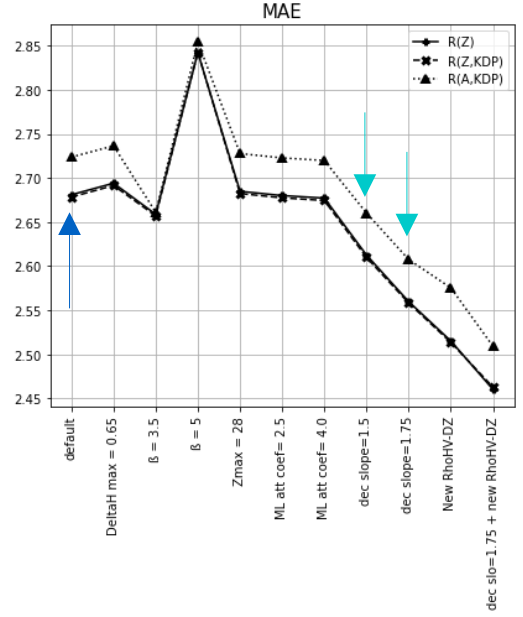








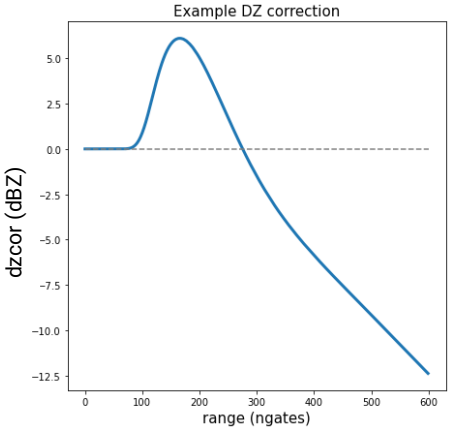




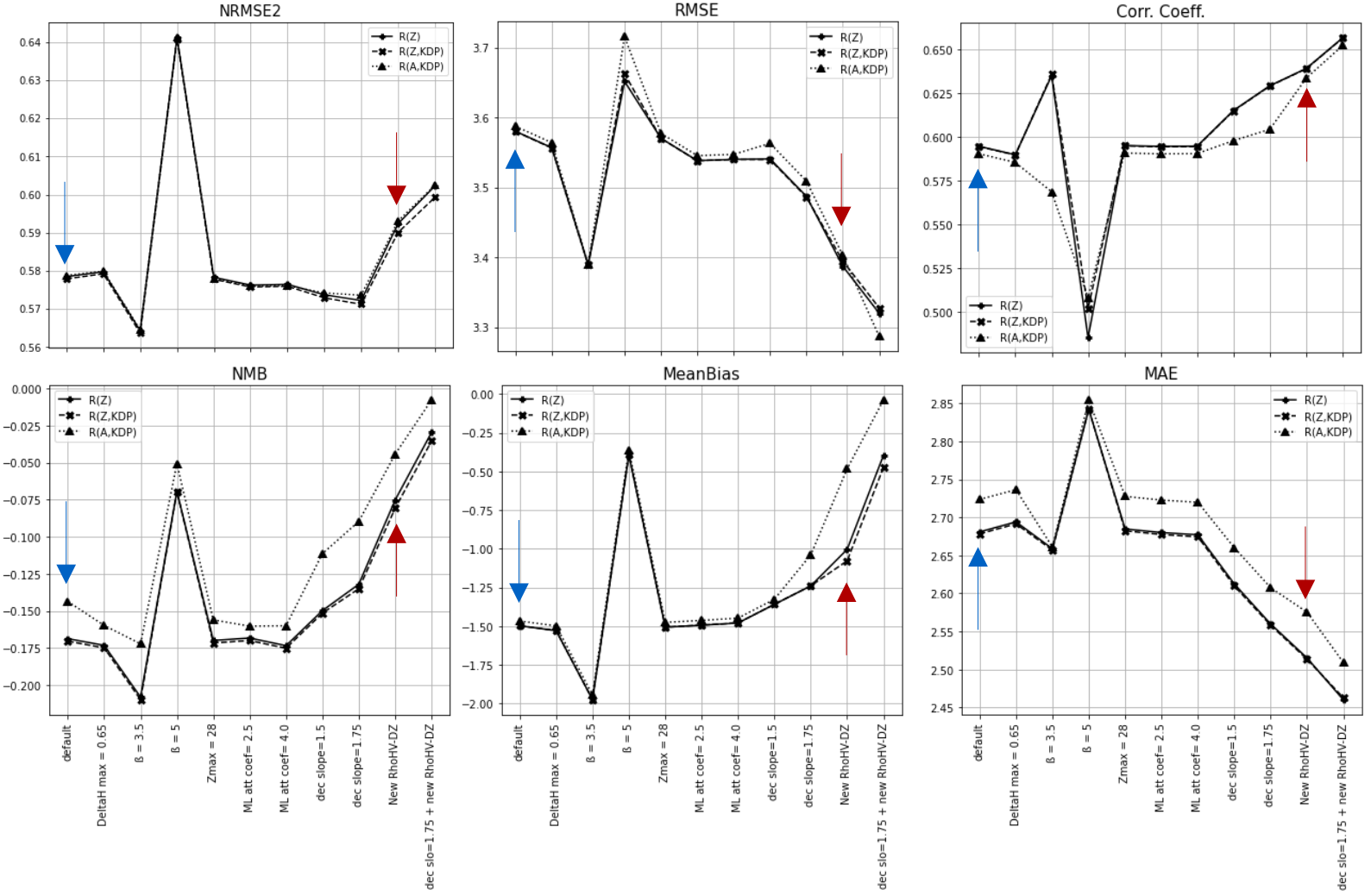
default

Change decreasing slope

- Improves all metrics
- More pronounced improvement for more intense decreasing slope



Statistics for all rain events in January 2018

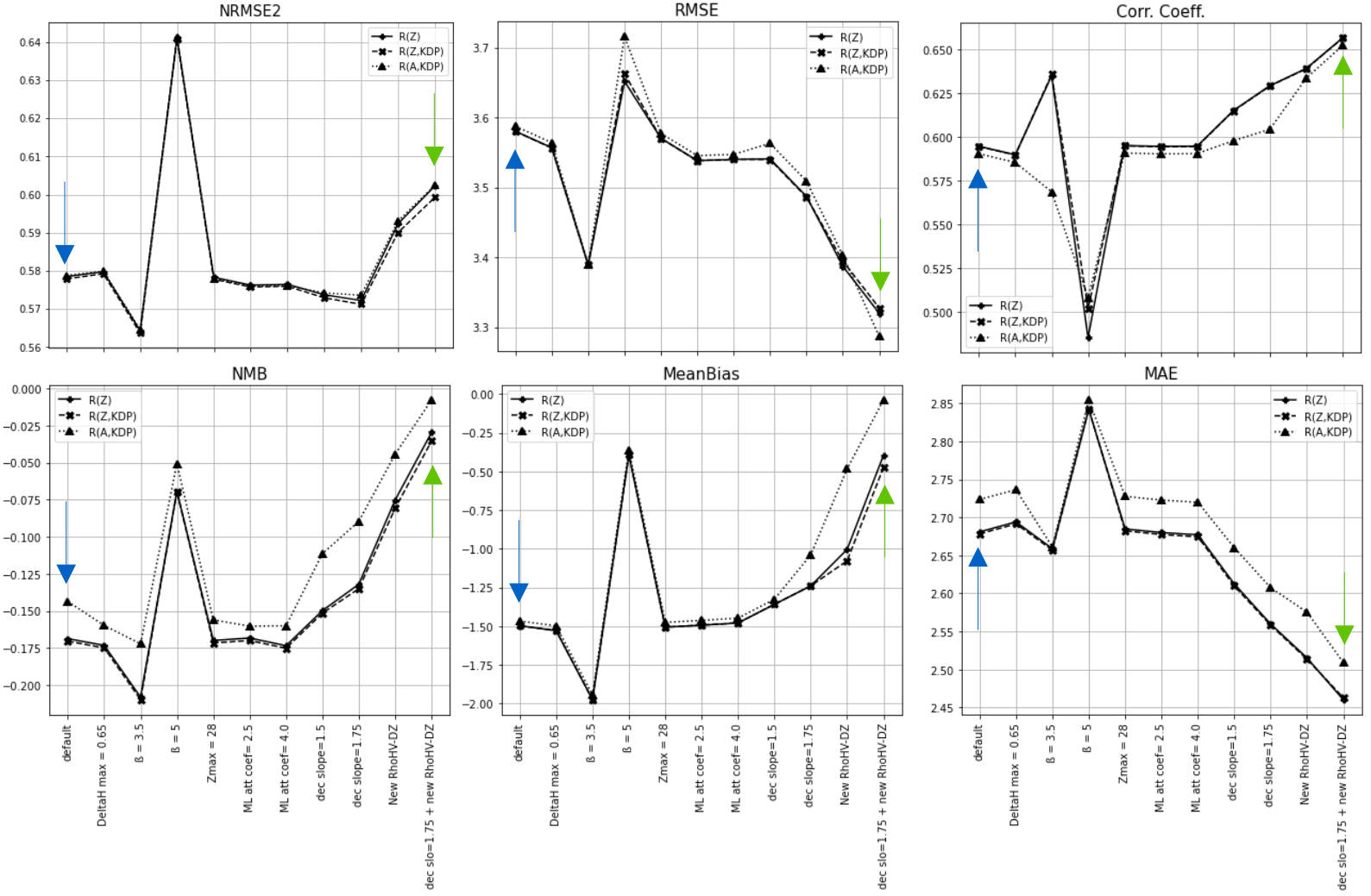


default

New ΔZ-minρ_{HV} rel.

- Significant improvement in all metrics
- Except NRMSE

Statistics for all rain events in January 2018

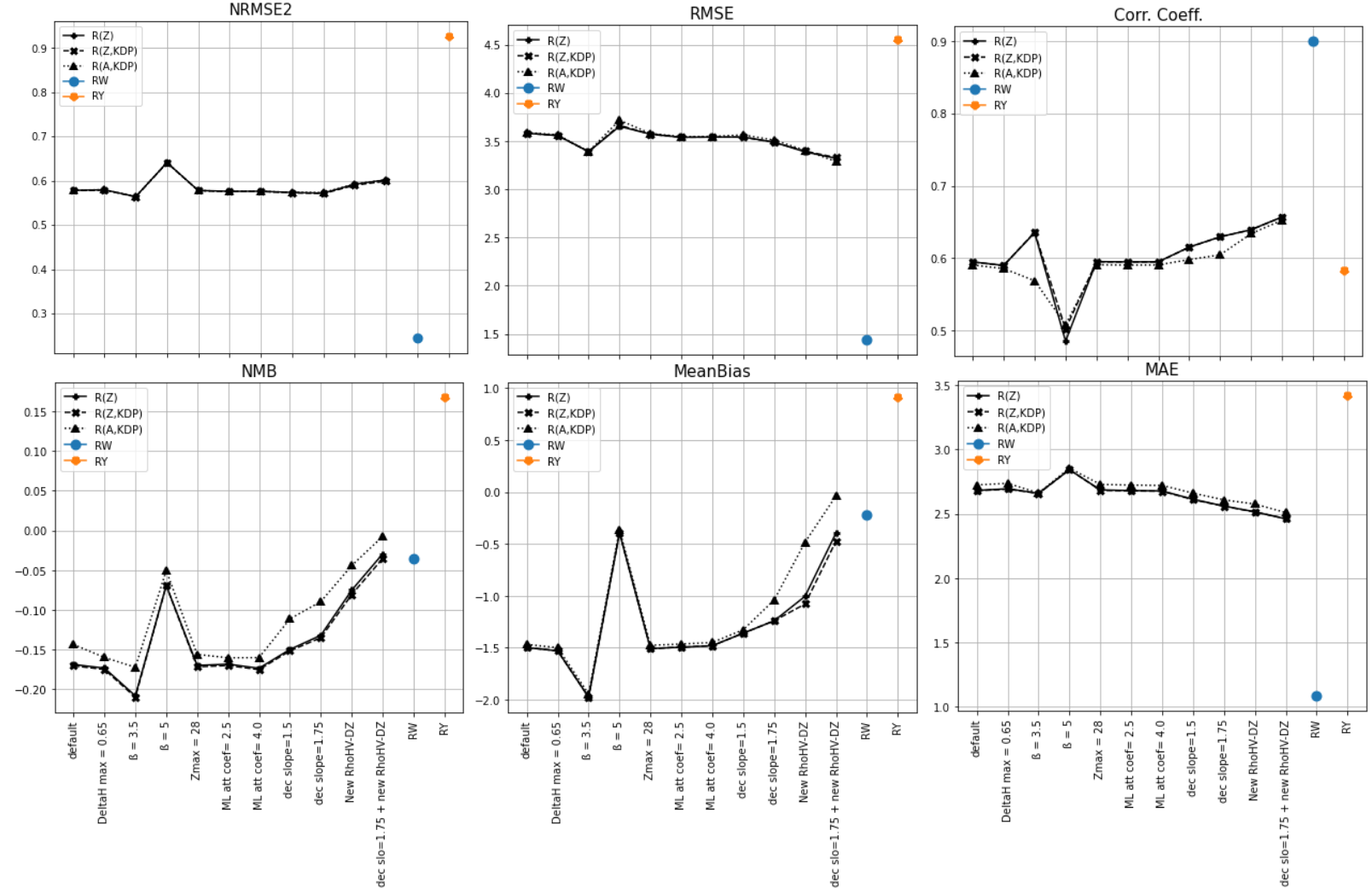


default

Enhanced decreasing slope + New ΔZ-minρ_{HV} rel.

- Shows the most improvement in all metrics
- Except NRMSE

Comparison with the DWD products



RW

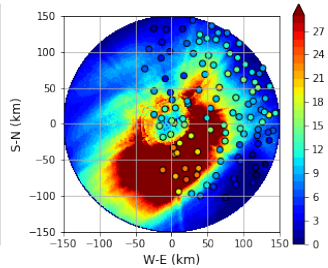
- Hourly product adjusted to rain gauges
- performs better for all metrics

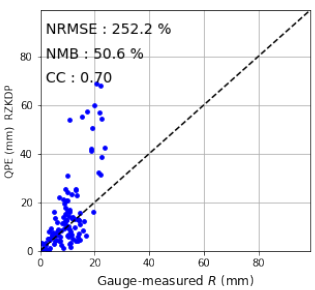
RY

- Radar only product 5 min resolution
- performs worse for all metrics

Example 24h accumulation

No PVPR





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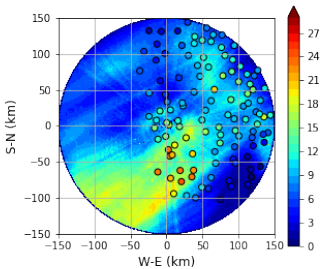
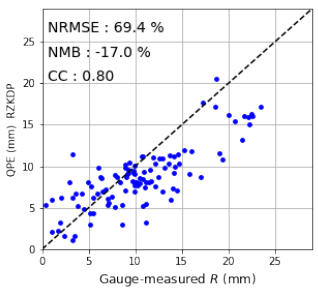
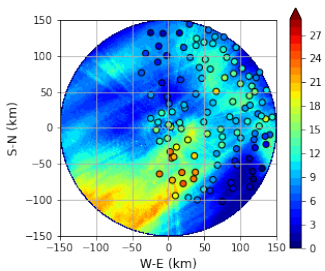
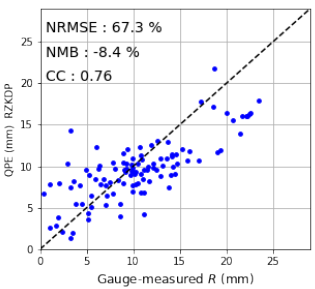


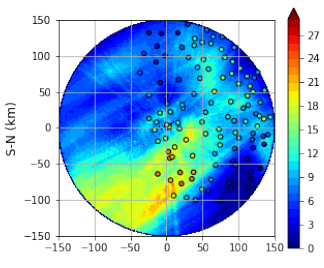


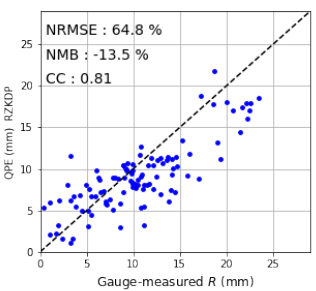
β = 5 dB/km



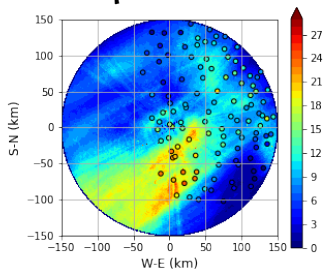


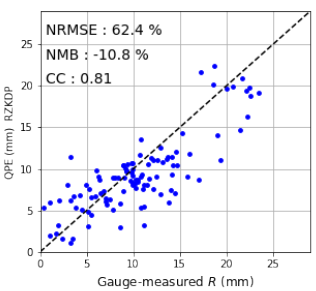
dec slope: 1.75



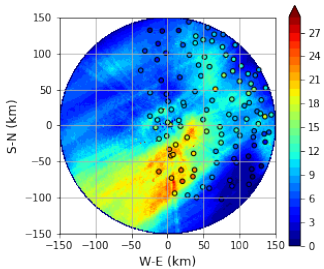


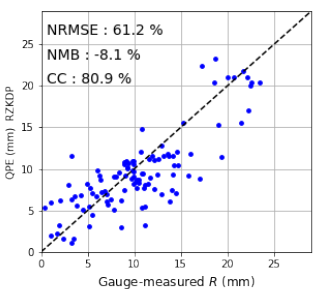
New New ΔZ-minρ_{HV} rel





Combined





20180125 Nhb

Summary

- PVPR technique shows clear improvements in QPE
  - Removing the effect of the ML
  - Improving the rainfall at far ranges
- Updates were made to the parameters based on local climatology
- The best results were achieved with a combination of the enhanced decreasing slope and the updated relationship between ΔZ and $\min \rho_{HV}$.
- Comparing with existing products:
  - PVPR better performance than RY (comparable product fully radar derived with 5 min resolution)
  - PVPR performs worse than RW (product adjusted to the rain gauges measurements)
- Comparisons with other R(Z) relationships used in Germany showed that the derived R(Z) relationship from Chen *et al.* 2021 performs the best (not shown)

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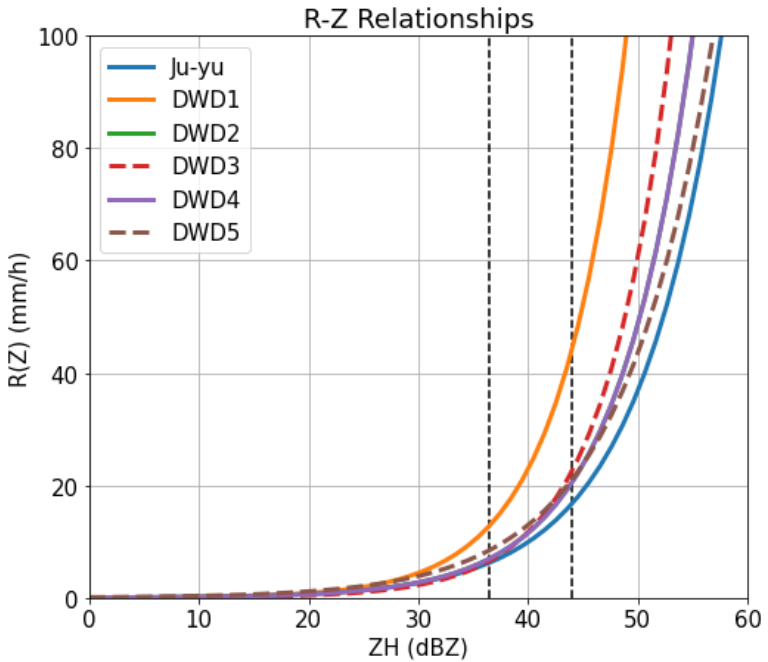
Tests with different R-Z relationships

Tabelle 4.1: Verfeinerte Z/R-Beziehungen

dBZ	< 36.5			36.5 … 44	> 44
Schauerindex $\overline{\Delta}$	< 3.5	3.5 … 7.5	> 7.5		
Parameter a	125	200	320	200	77
Parameter b	1.4	1.6	1.4	1.6	1.9
	DWD1	DWD2	DWD3	DWD4	DWD5

$$Z = a \cdot R^b$$

DWD2 = DWD4



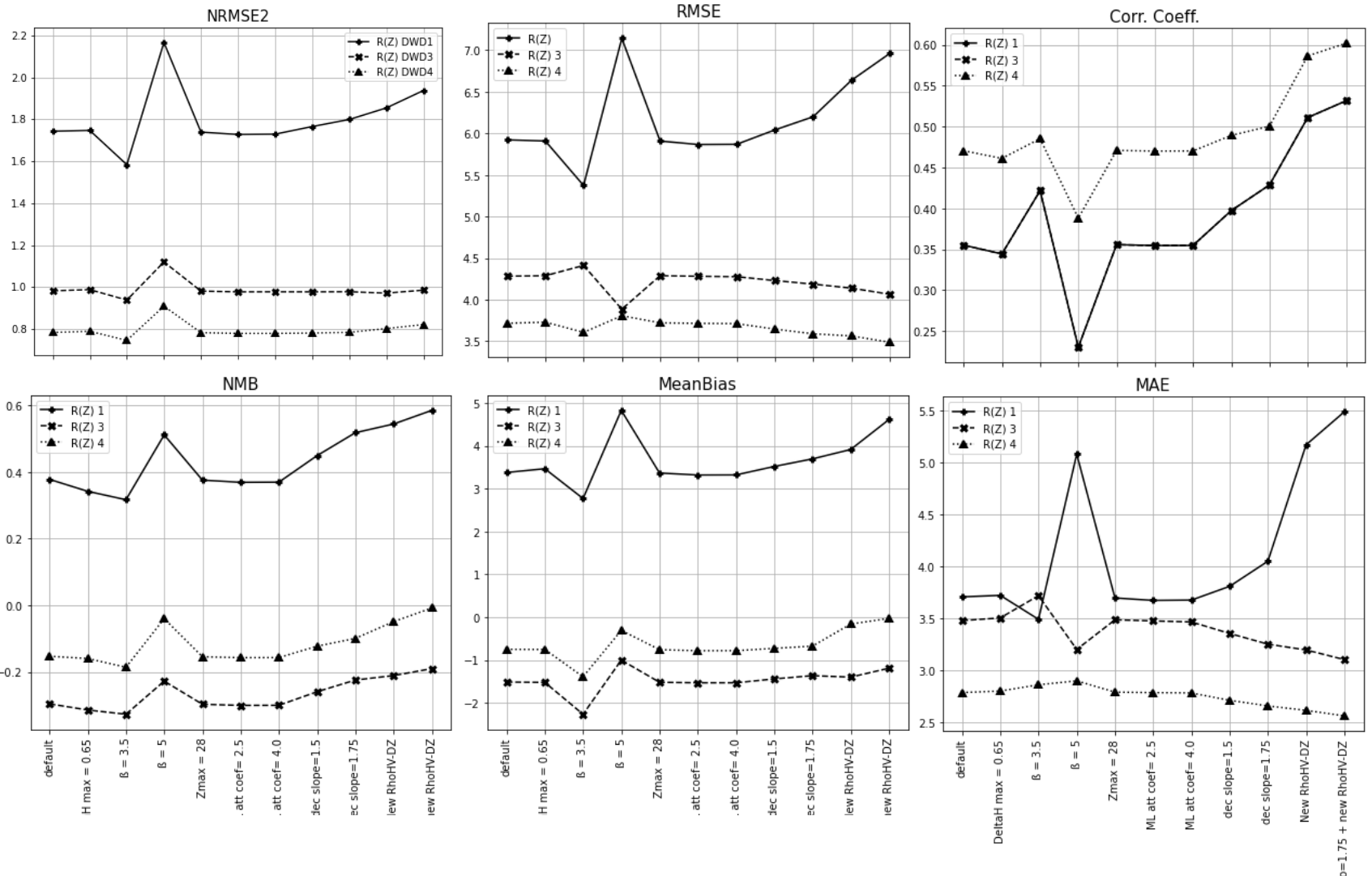
Ju-yu's relation:

$R(Z) = 0.052 \cdot Z_h^{0.57}$

$Z = 179 \cdot R^{1.75}$

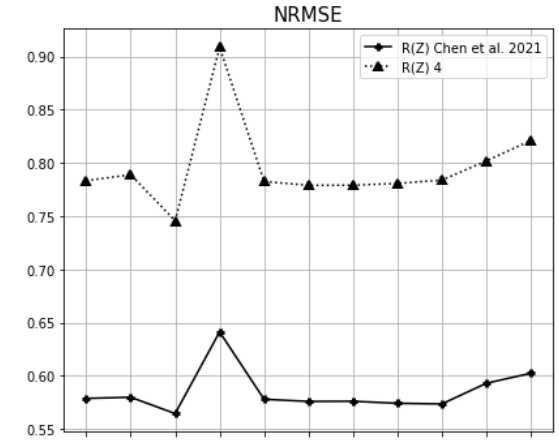
a = 179 ; b = 1.75

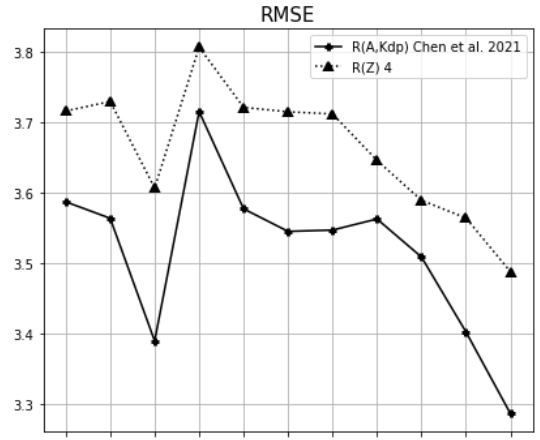
Tests with different R-Z relationships

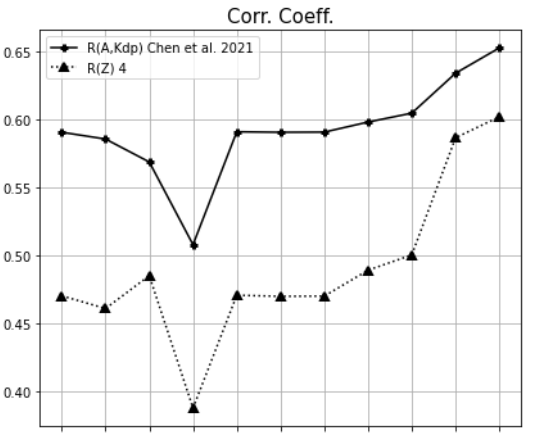


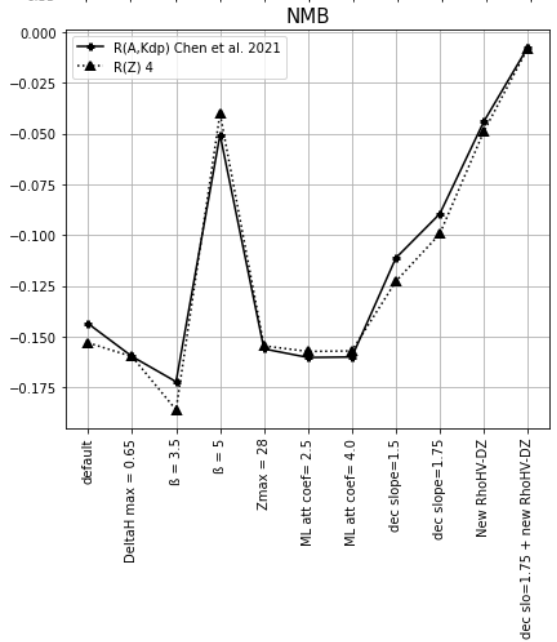
R(Z) 4 is the best by all metrics.

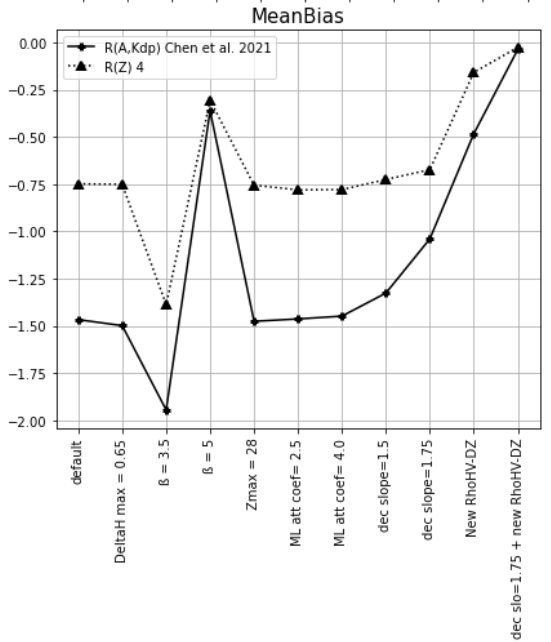
Tests with different R-Z relationships

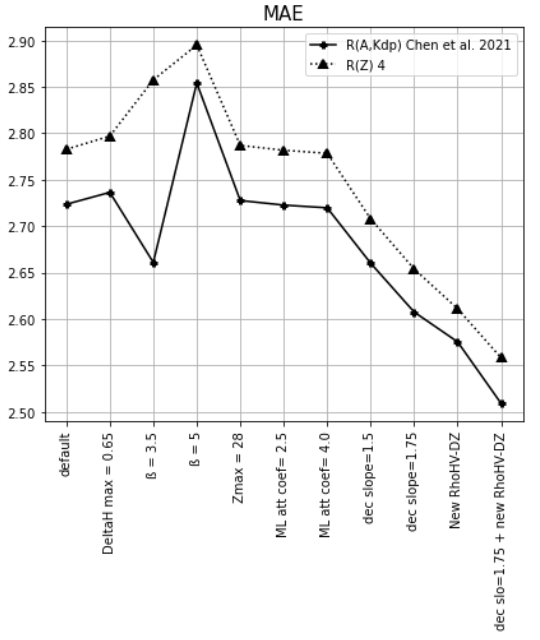












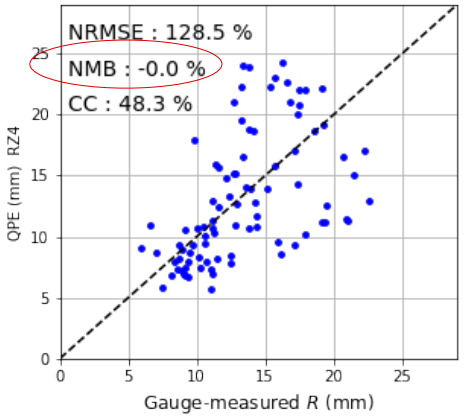
R(Ah,Kdp)

vs

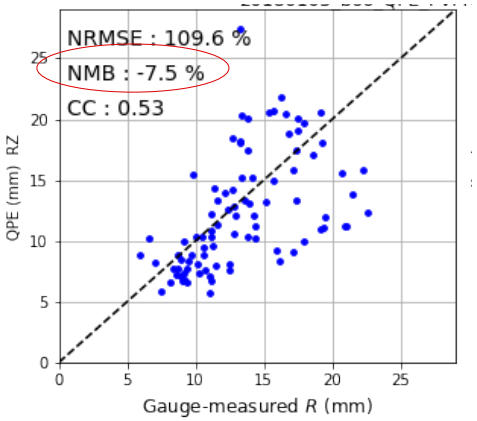
R(Z)4

R(Ah,Kdp) outperforms R(Z)4 in all metrics (except mean Bias)

DWD RZ4



Ju-Yu RZ



20180103 boo PVPR

New min(ρ)-max(Z) for Germany

(PVPR 1N1_4N1_7N1)

The Lookuptables

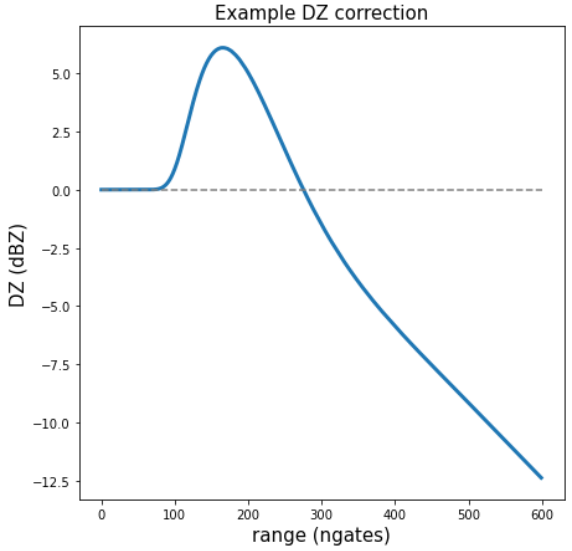
- H_b = 0.2, 0.4, ...3.0 km (15 values)
- ΔH = 0.55, 0.53, 0.51, 0.49, 0.45, 0.40, 0.36, 0.32 km (8 values)

Lookuptable:

dzcor.shape = [15,8,600]

H_b = Height of ML bottom

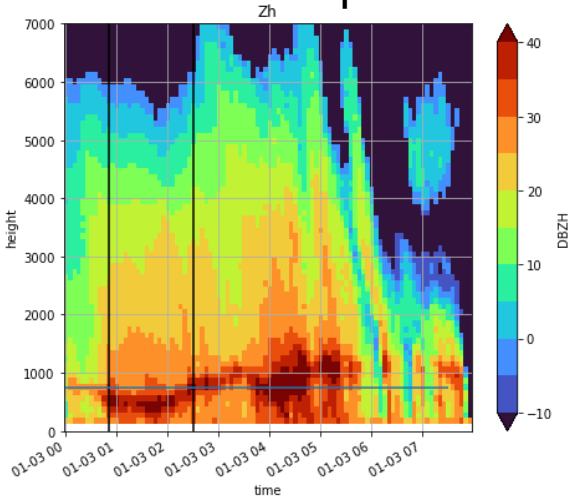
ΔH = ML thickness

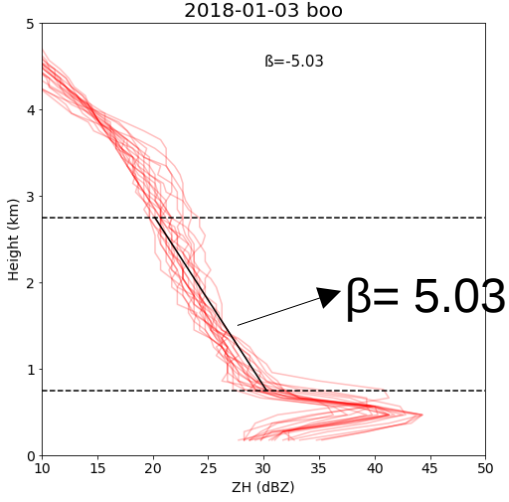


$$Z_{H,cor} = Z_H - dzcor$$

Event Variability

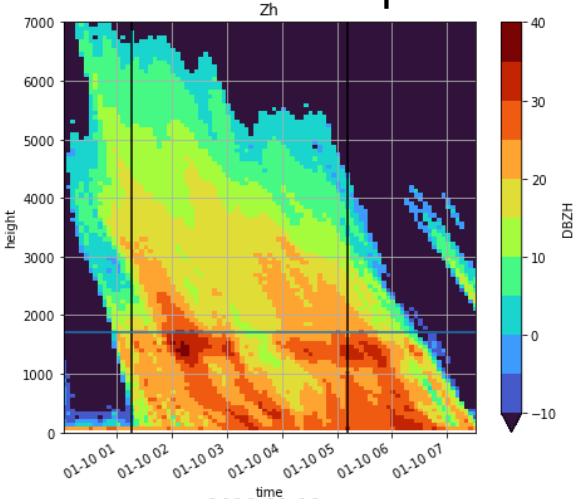
Improved scores with β= 5 dB/km

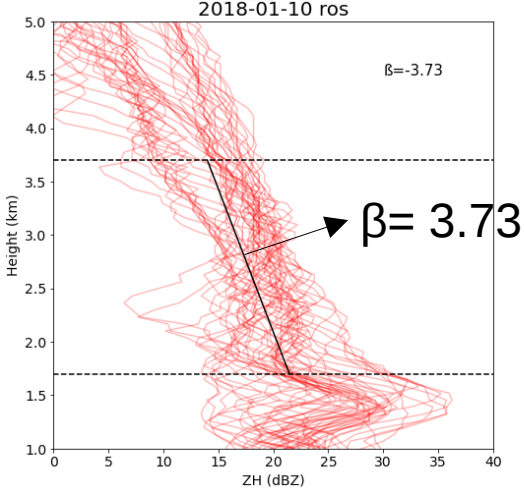




β= 5.03 dB/km

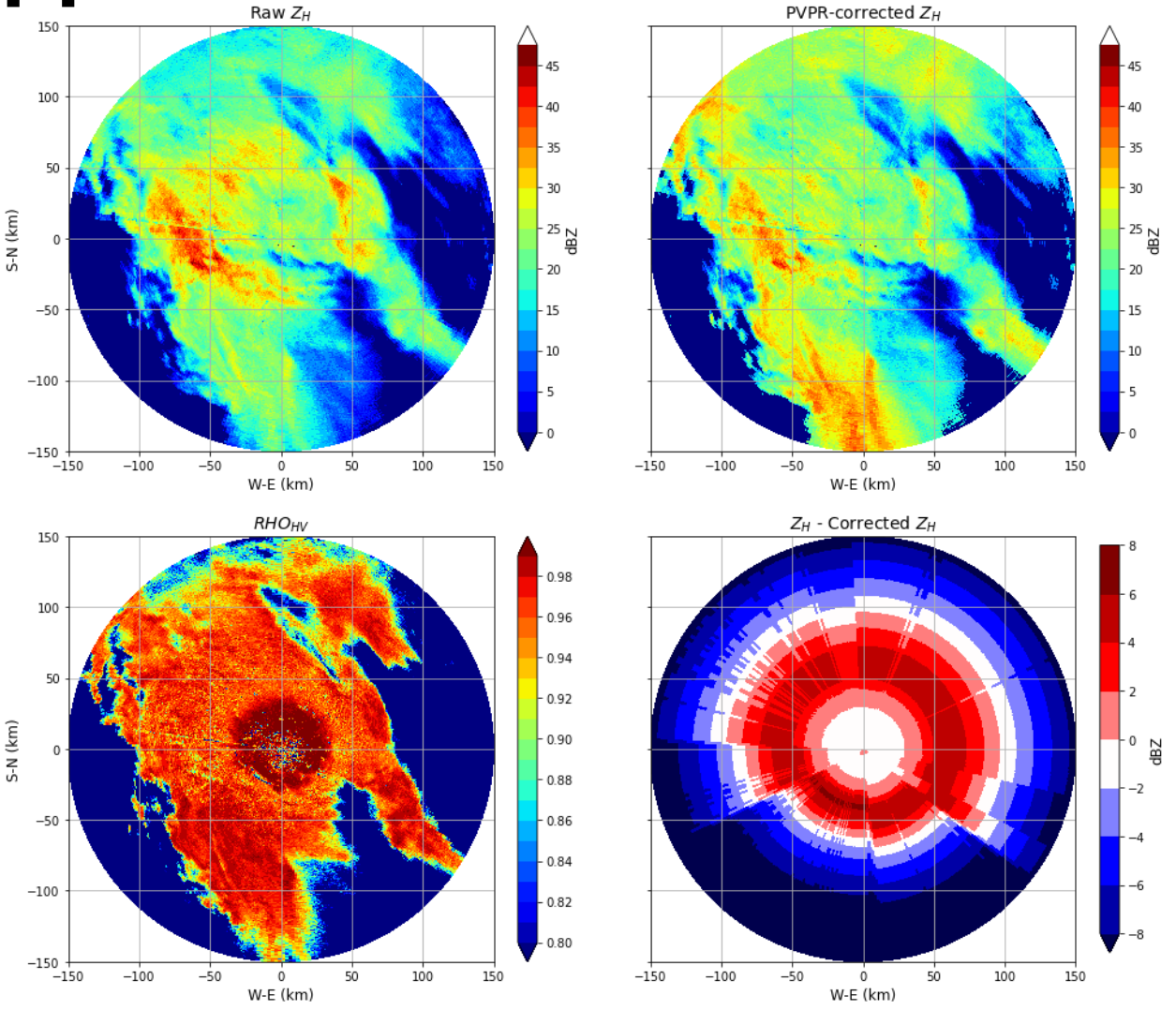
Improved scores with β= 3.5 dB/km





β= 3.73 dB/km

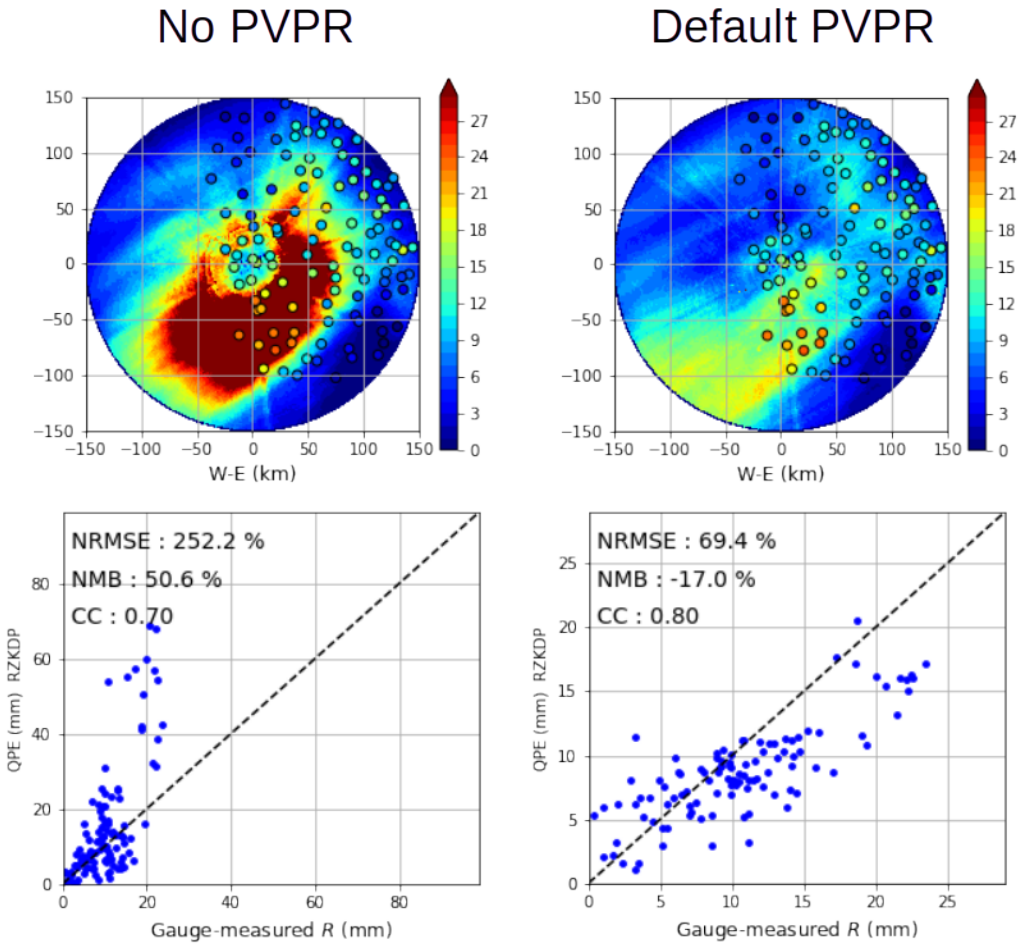
Application of PVPR Method

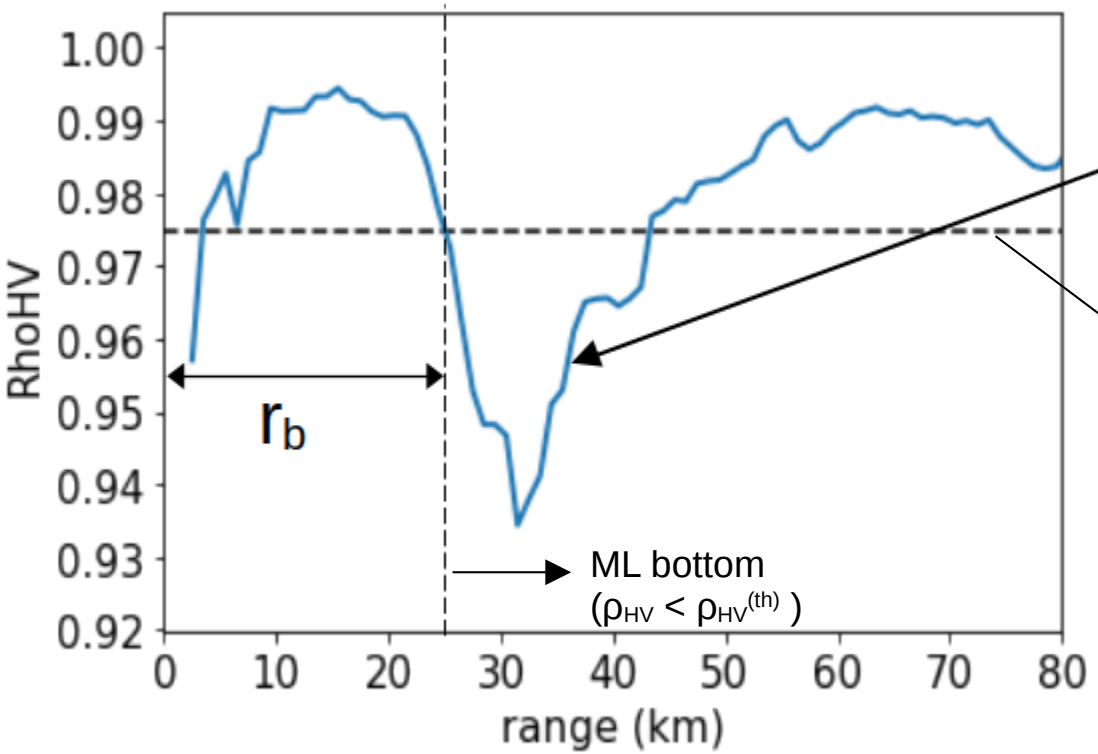


Application of PVPR Method

Rainfall 24h accumulation

20180125 Nhb





$$S = \int_{r_b}^{r_t} [\rho_{hv}^{(th)} - \rho_{hv}(r)]dr$$

$\rho_{HV}^{(th)} = 0.975$