RealPEP Meeting, Berlin, 9 October 2024

P1: Status on the QPE-products for RealPEP: Polarimetric VPR for ML correction

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RealPEP

Work packages

- **WP-P1-1: Joint evaluation, data provision and operationalization**
  - ✓ Evaluate methods and estimators on a large dataset
  - ✓ Synchronise evaluation with other projects
  - ✓ Identify remaining deficiencies
  - ✓ Perform evaluation with a semi-operational system in POLARA

  → ✓ In progress: see tomorrow at Mahfuja Akter's talk

- **WP-P1-2: Polarimetric QPE refinement by α segmentation**
  - ✓ Identify hail cores and segments with PHIDP bumps
  - ✓ Apply the ZPHI method to rainy segments
  - ✓ Derive segment-wise α estimates
  - ✓ Estimate uncertainties

  → ✓ Ju-yu Chen: done

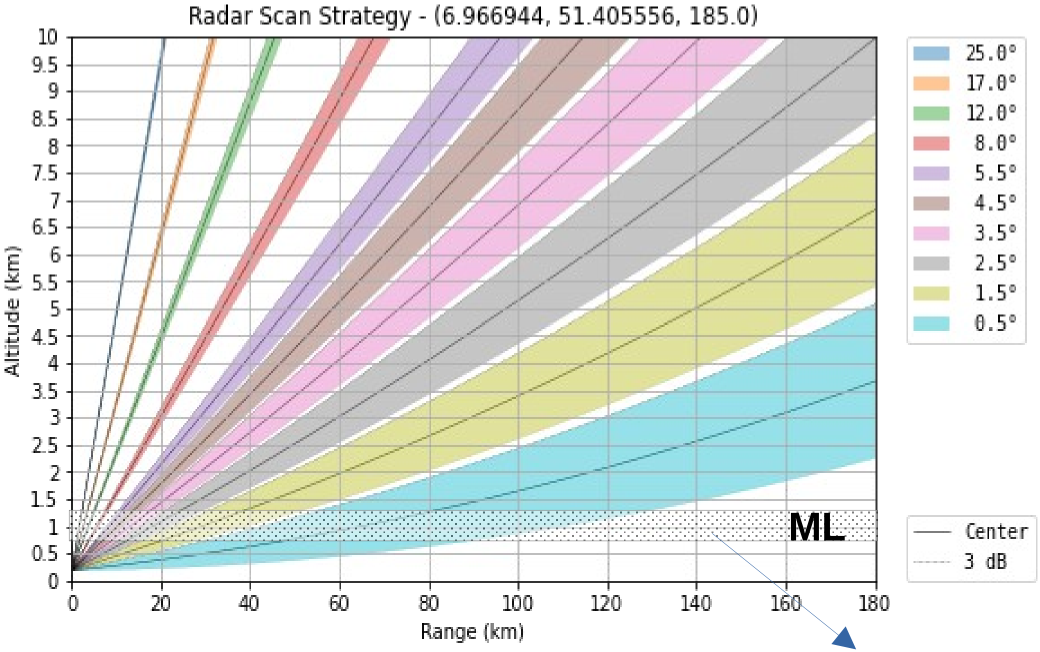
- **WP-P1-3: Polarimetric QPE in snow and mixed-phase regions**
  - ✓ Apply polarimetric VPR (PVPR) in heterogeneous rain
  - ✓ Improve retrievals for snowfall intensity

  → ✓ In this presentation

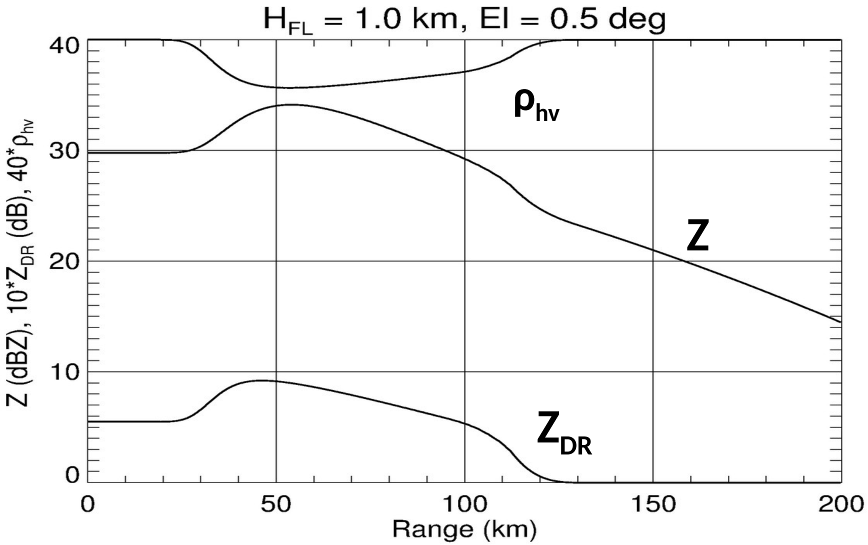
- **WP-P1-4: Probabilistic merging at increasing resolutions**
  - ✓ Error estimation and bias correction between QPE products
  - ✓ Formulate a Bayesian merging framework
  - ✓ Use estimated uncertainty to derive ensemble QPE

The problem

Vertical cross- section DWD radar scan



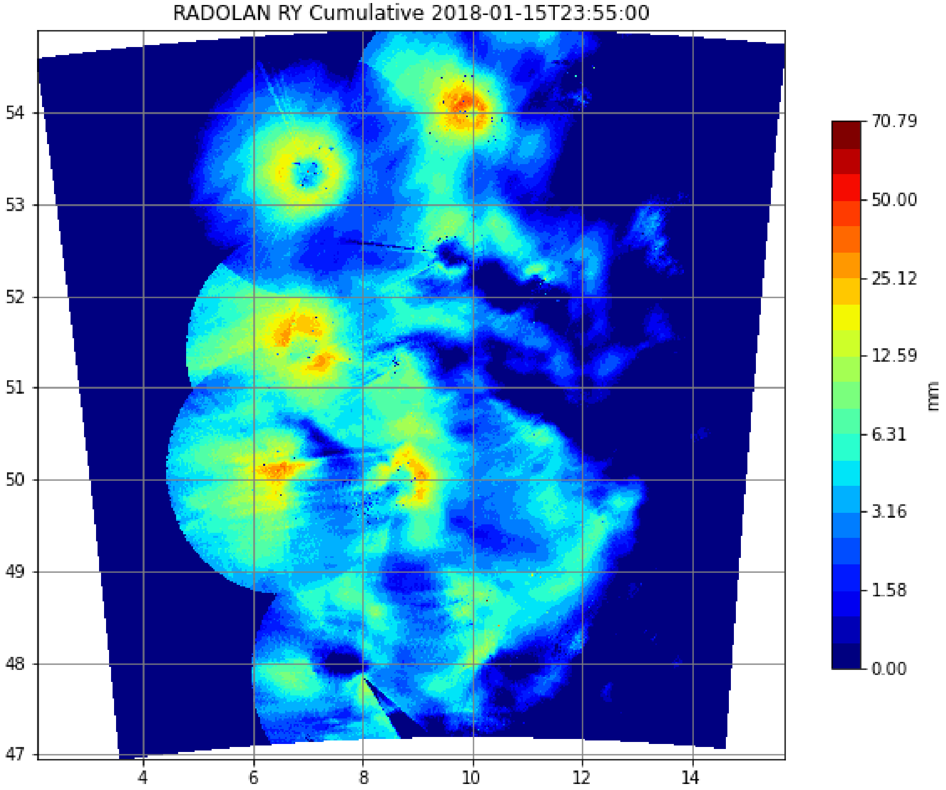
Radial profile of Z_H, Z_{DR} and ρ_{HV}



Low Melting layer

The problem

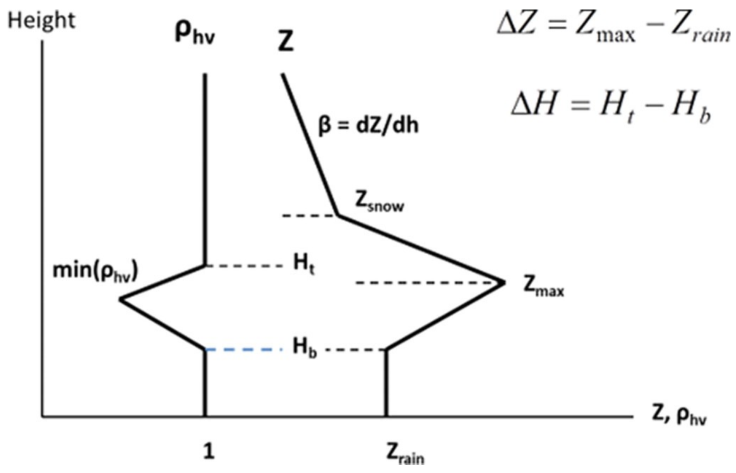
Composite Daily Rainfall over Germany



- 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}



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}.

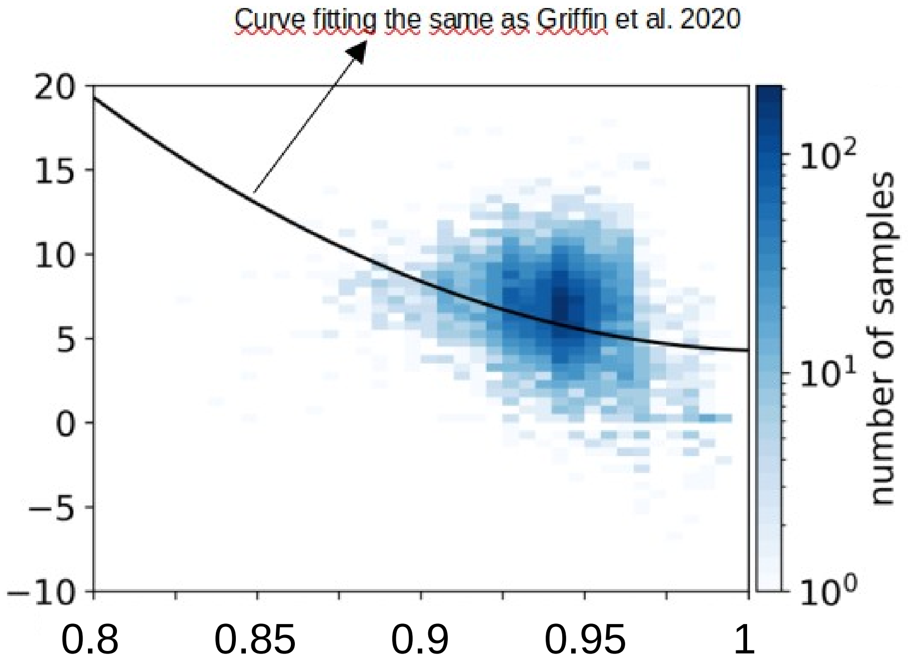
H_b = Height of ML bottom

ΔH = ML thickness

Methodology

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

- **Originally the method was developped by A. Ryzhkov for the USA**
- **Adapted to C-band and German climatology using 5 years (2015-2020) with the Prötzel radar – Julian Giles. Uni Bonn**



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

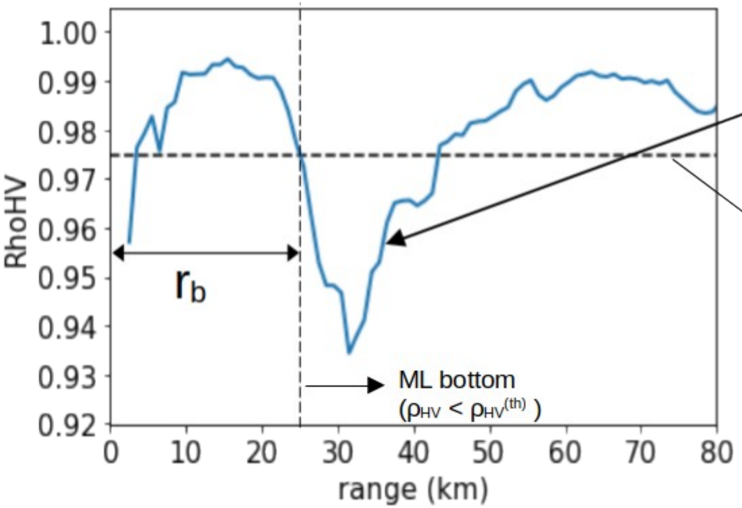
Methodology

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

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

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**

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

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

5) **Use the corrected Z_H profile to calculate rain rates**

The Lookuptables

- H_b = 0., 0.4, ..., 2.8 km (15 values)
- ΔH = 0.55, 0.53, 0.51, 0.49, 0.45, 0.40, 0.36, 0.32 km (8 values)

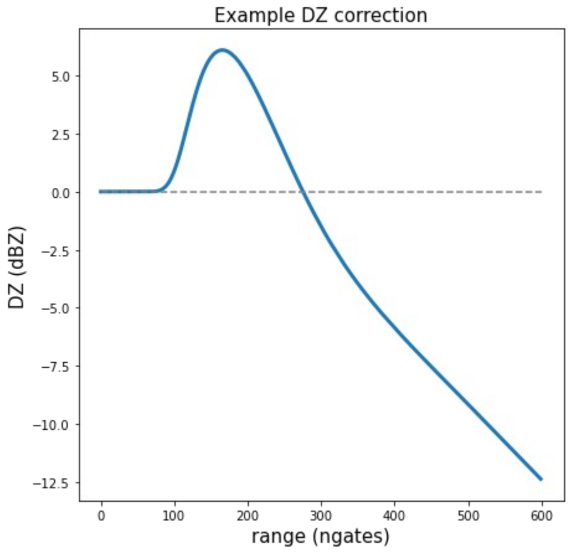
Lookuptable:

dzcor.shape = [15,8,600]

N of gates

H_b = Height of ML bottom

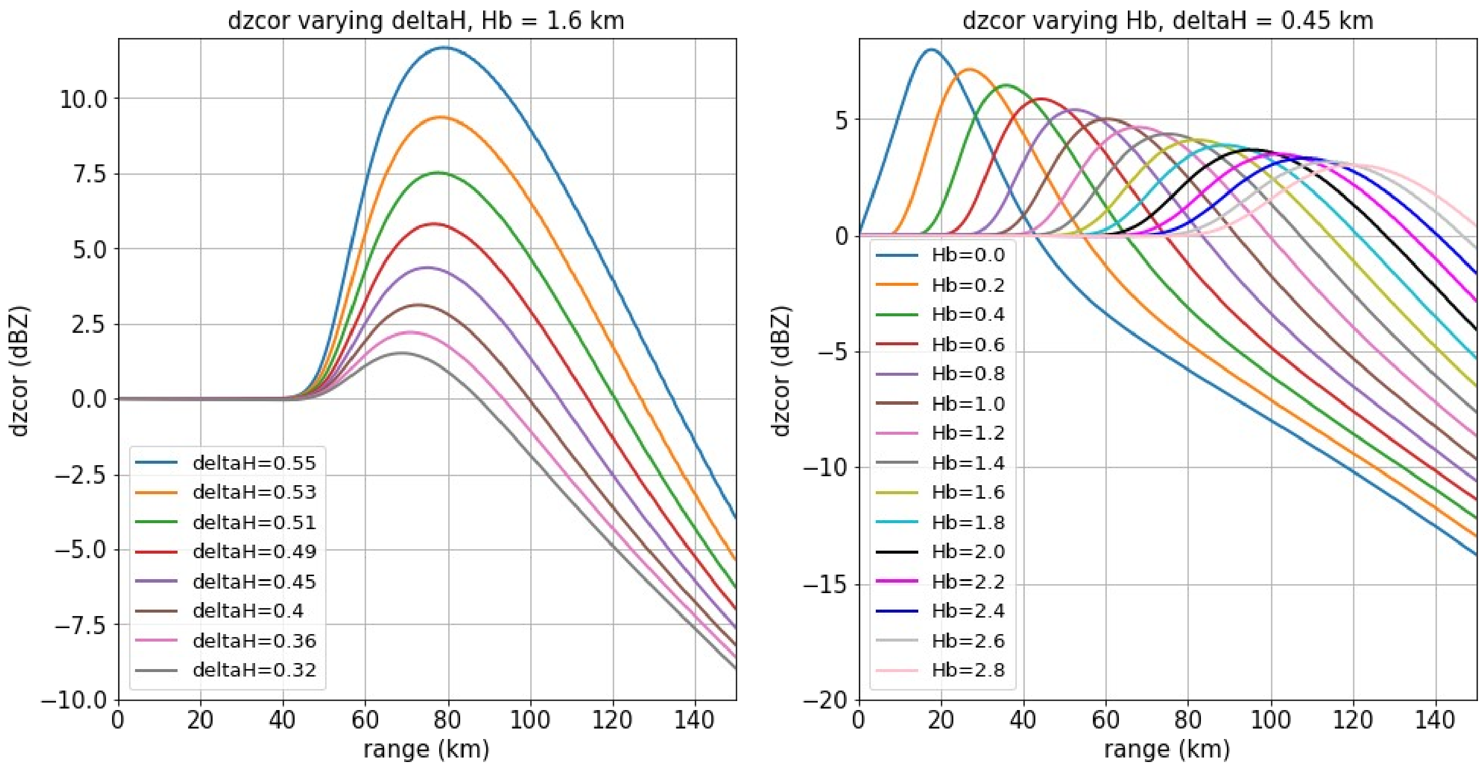
ΔH = ML thickness



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

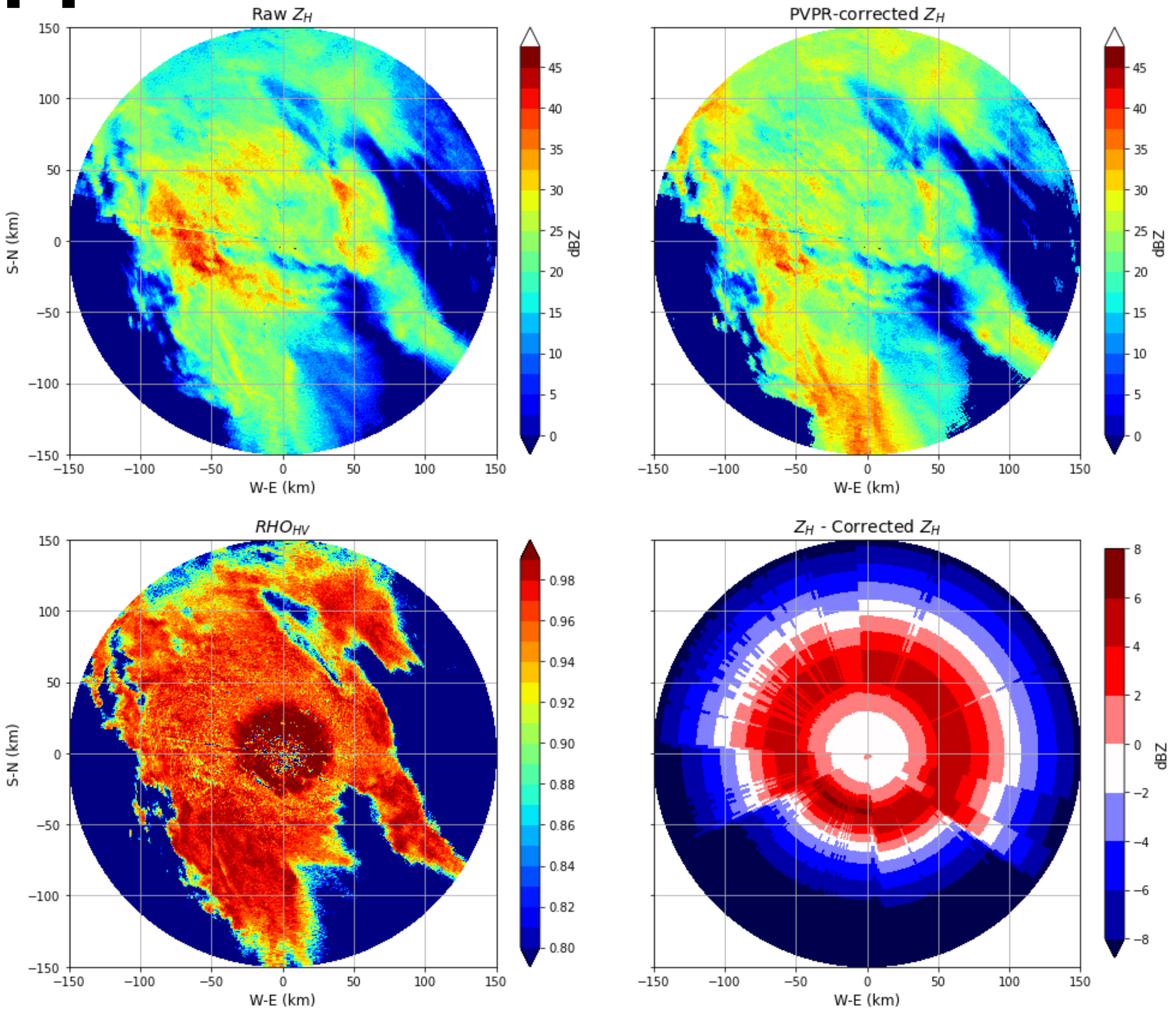
The Lookuptables

Default PVPR profile correction

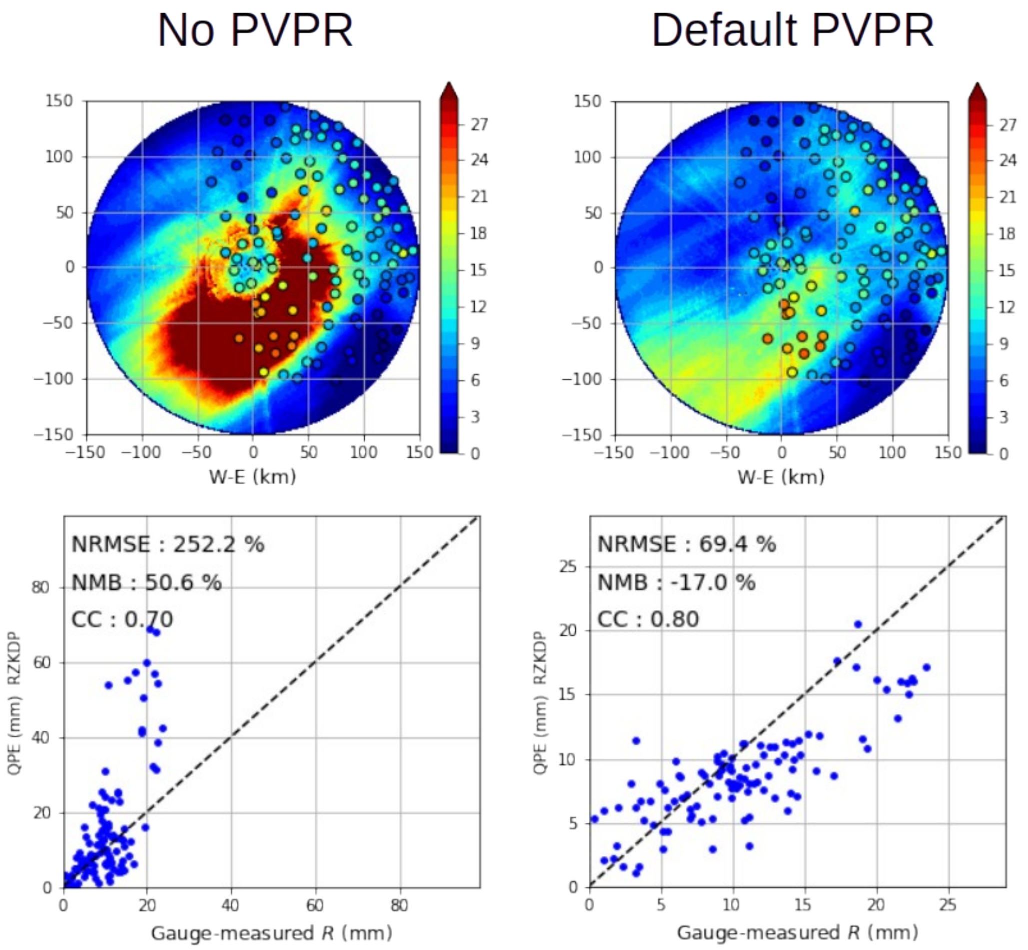


El = 1.0°

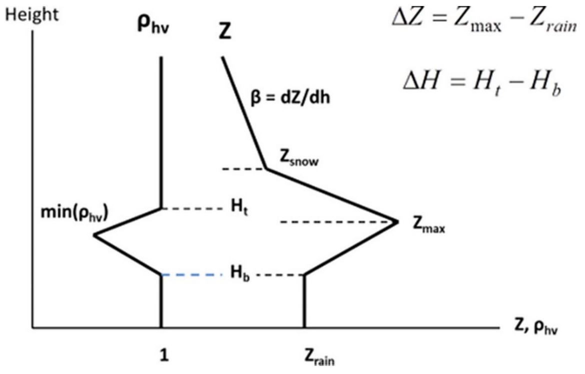
Application of PVPR Method

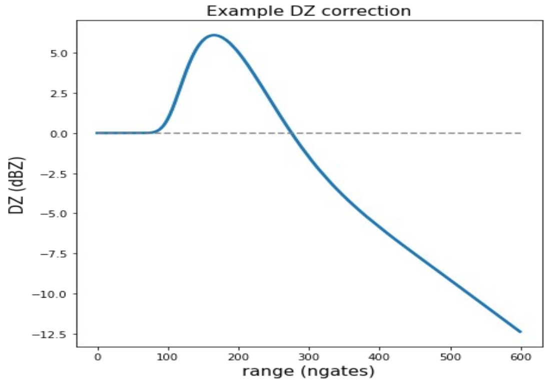


Rainfall 24h accumulation



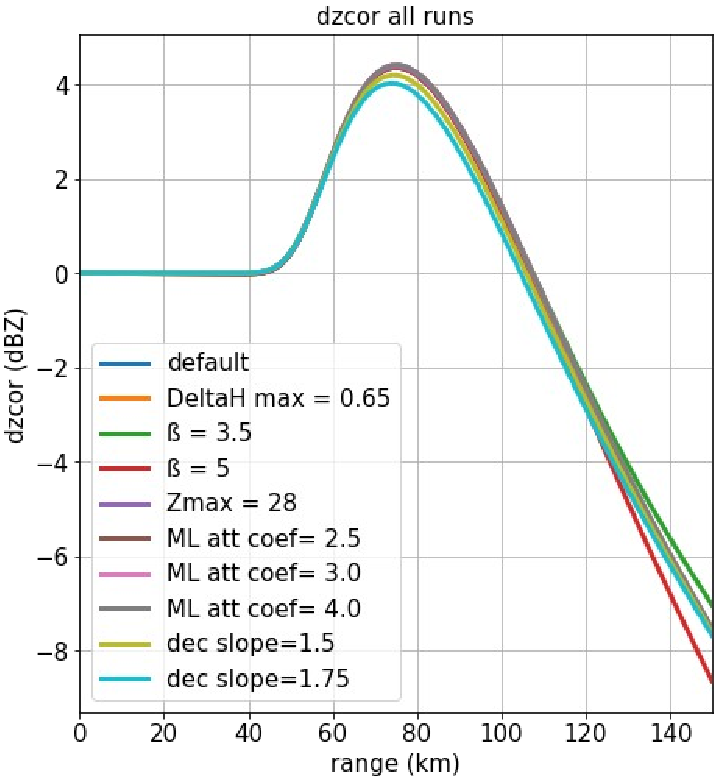
Testing different parameters

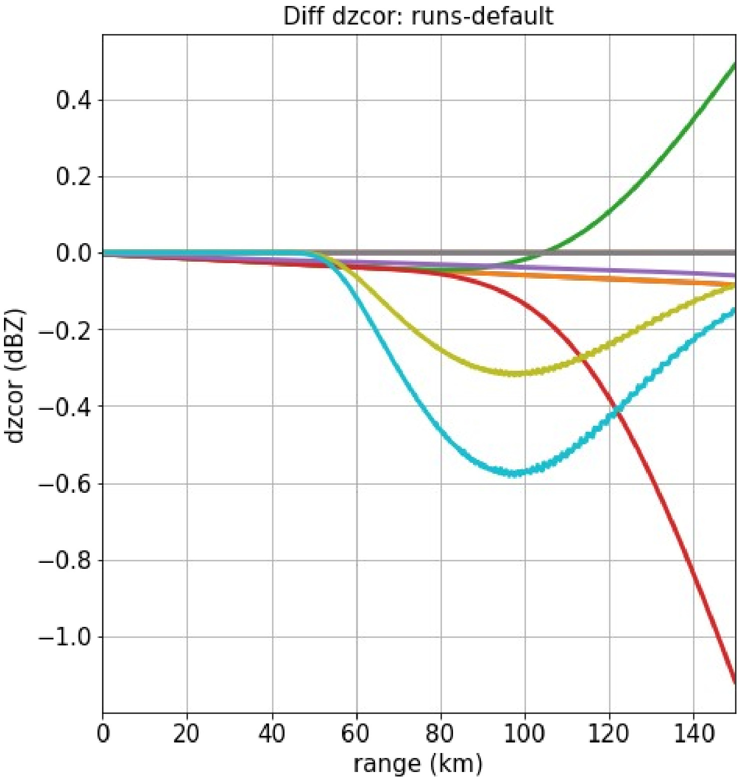




	Default	Runs
Max ΔH (km)	0.55	0.65
ß (dB/km)	4	3.5
		5
Zmax (dBZ)	30	28
Multiplicative factor to α within the ML	2.0	2.5
		3
		4
Decreasing slope after the ML peak	1.25	1.5
		1.75

Testing different parameters



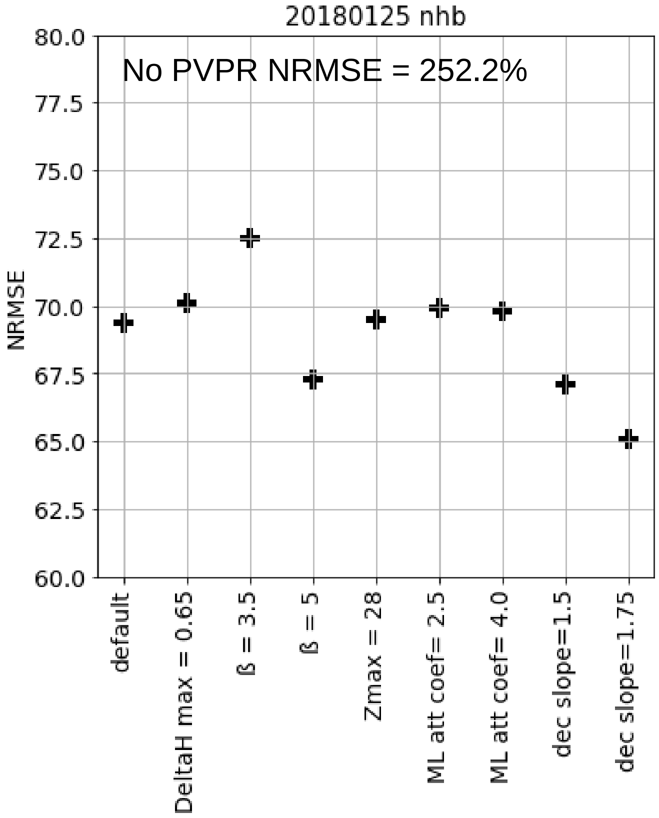


- Differences are mostly small
- Observed impact for changing
  - β at far ranges
  - Decreasing slope after the ML

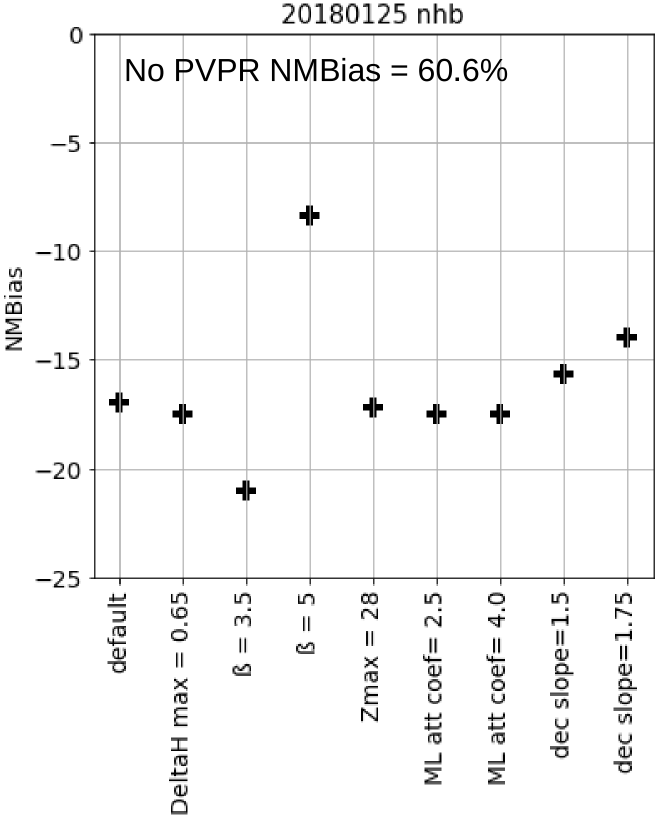
El = 1.0°, Hb = 1.6 km, ΔH = 0.45 km

Testing different parameters

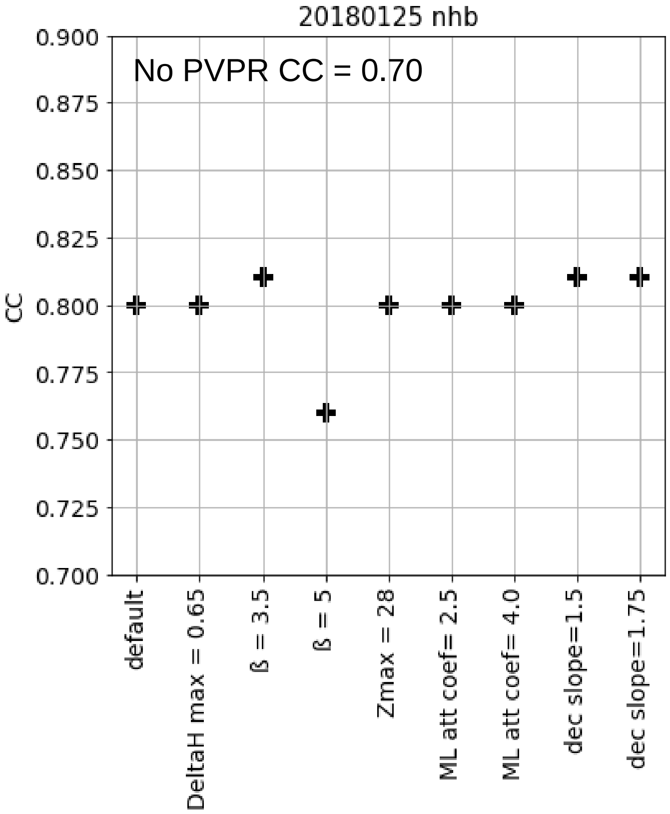
NRMSE



NMBias

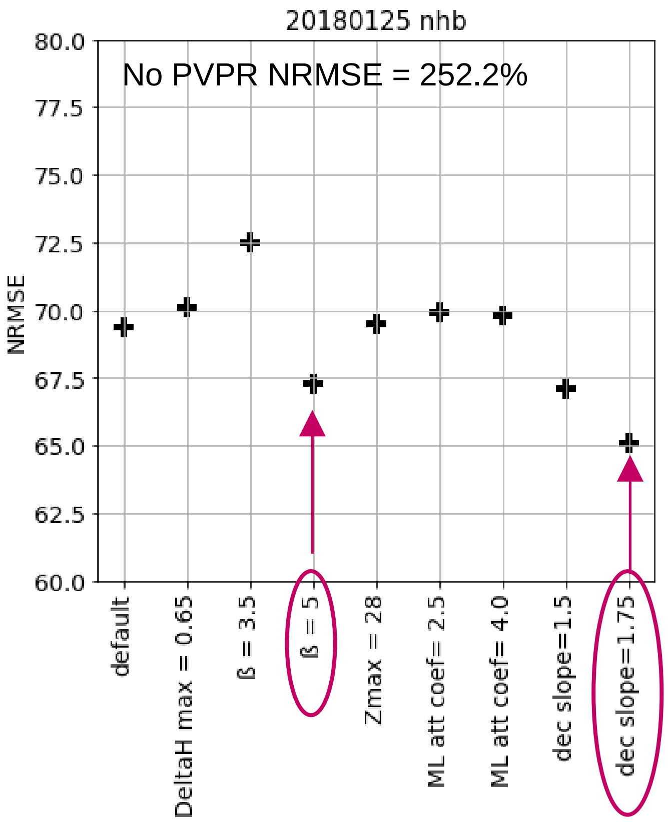


Correlation Coefficient

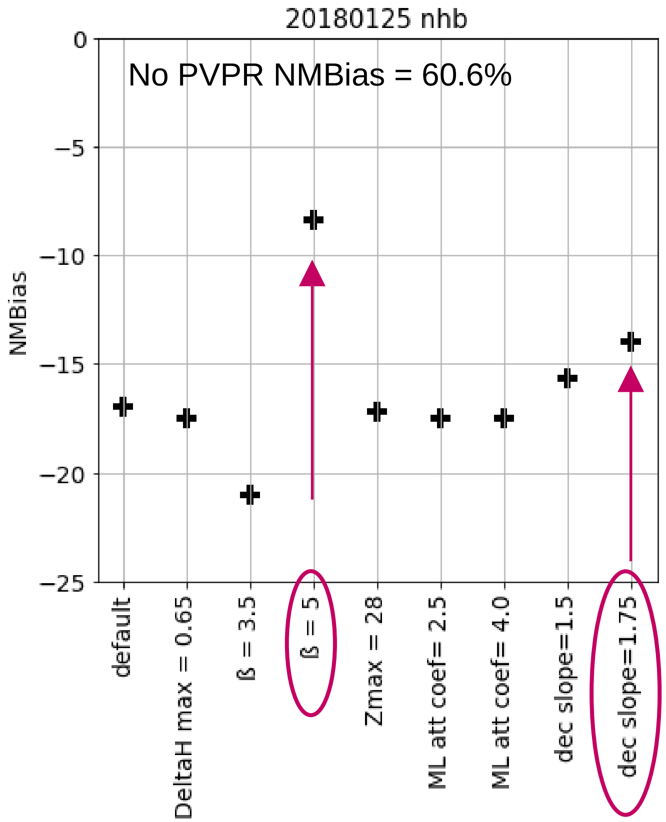


Testing different parameters

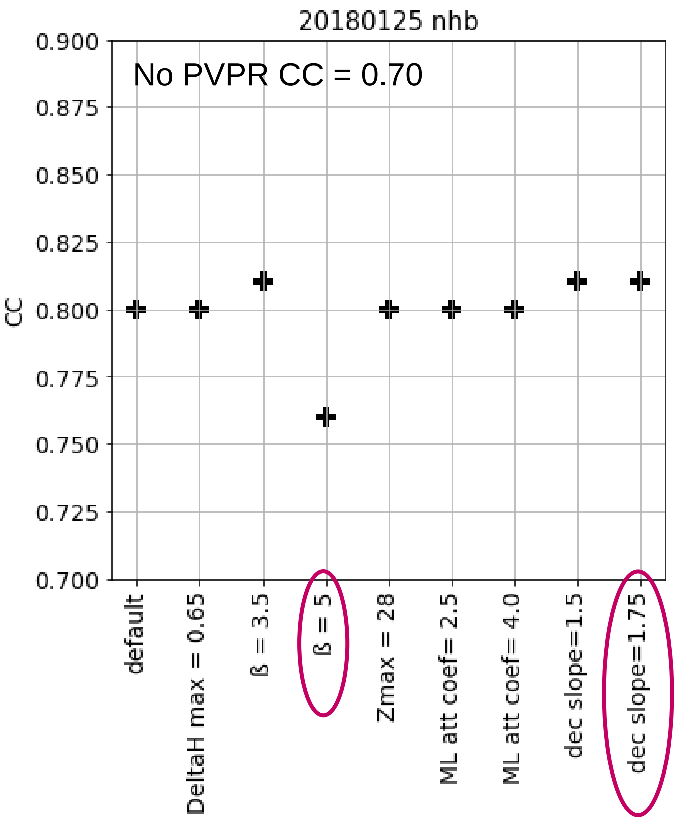
NRMSE



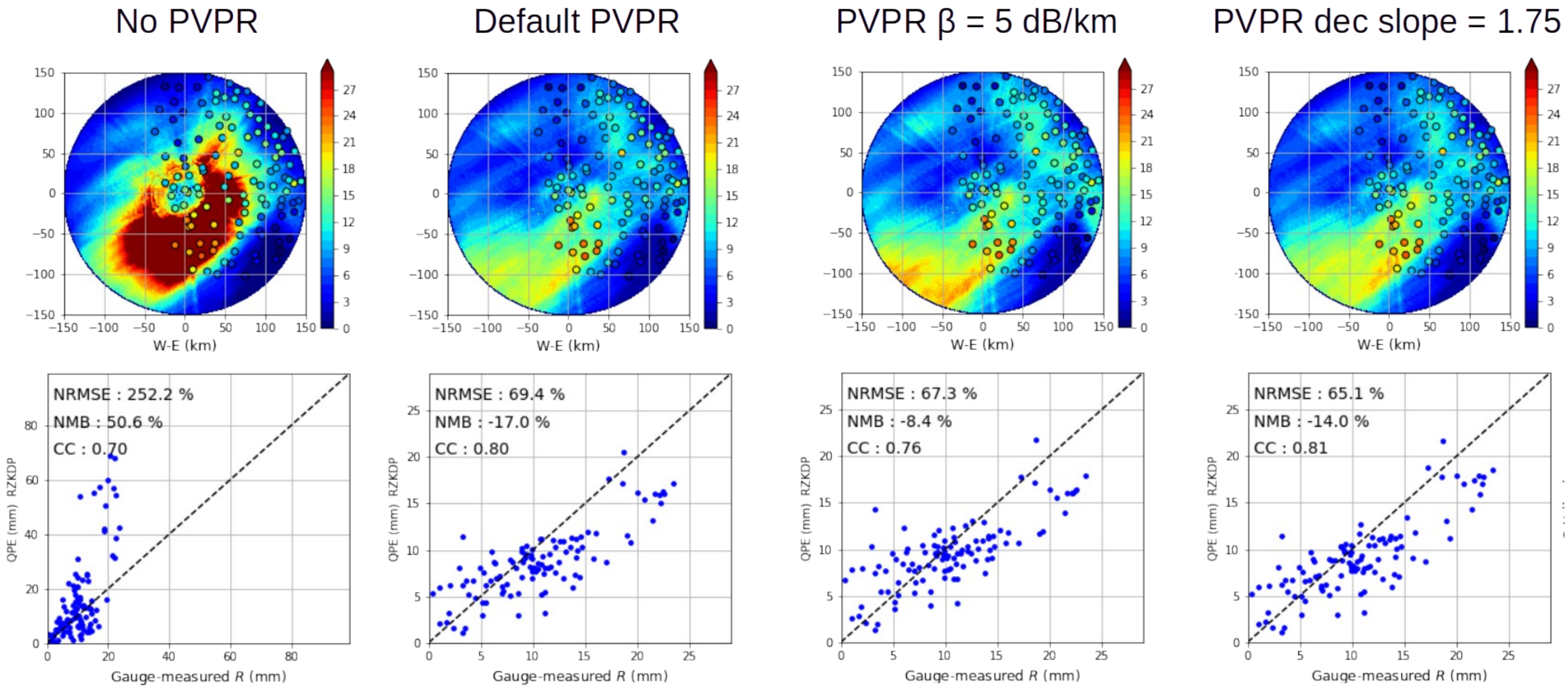
NMBias



Correlation Coefficient

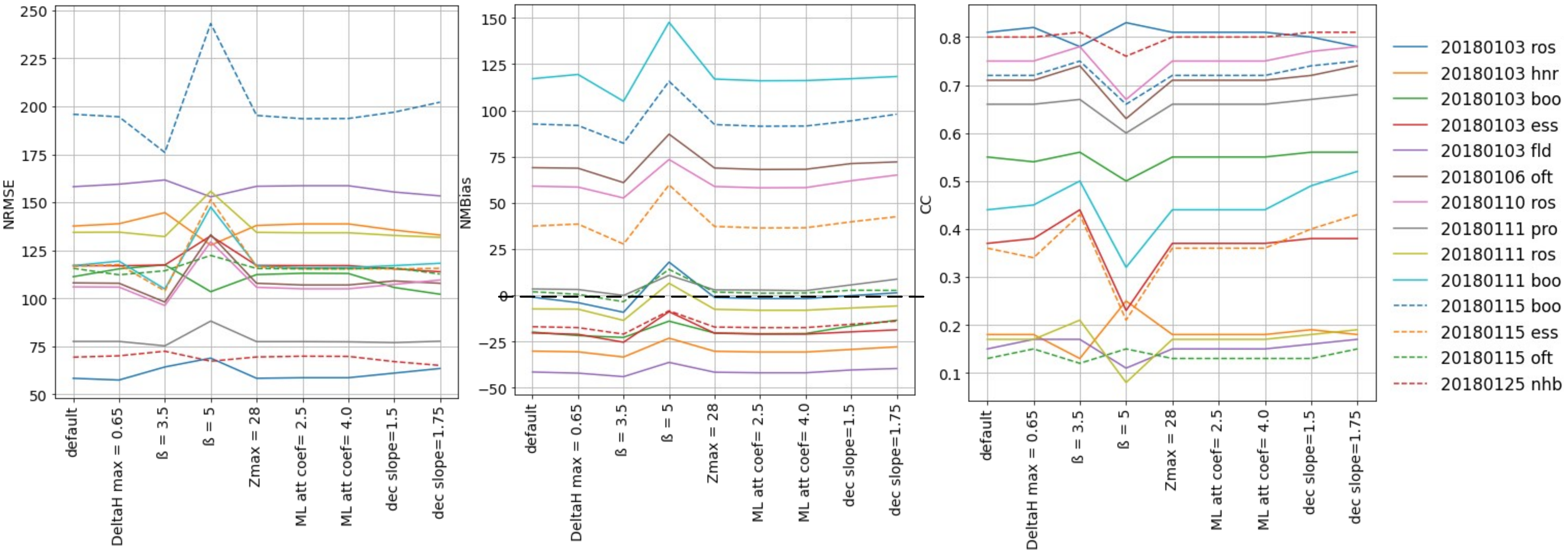


Rainfall 24h accumulation



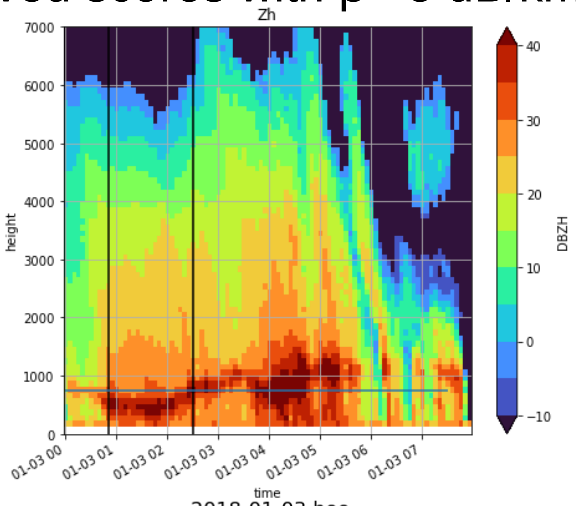
Validation Metrics

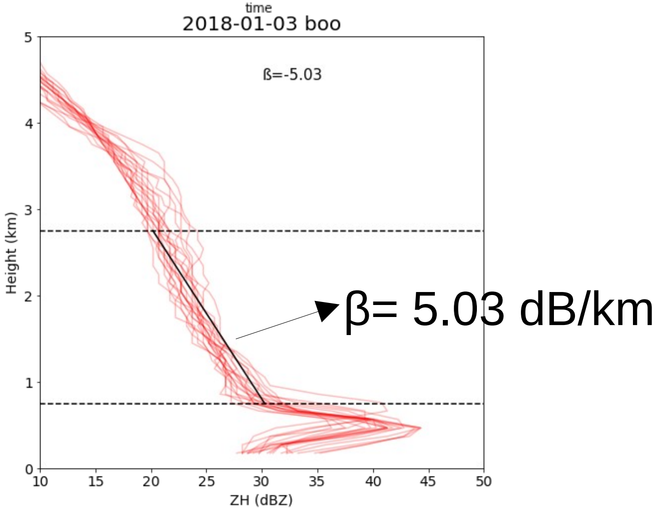
NRMSE NMBias Correlation Coefficient



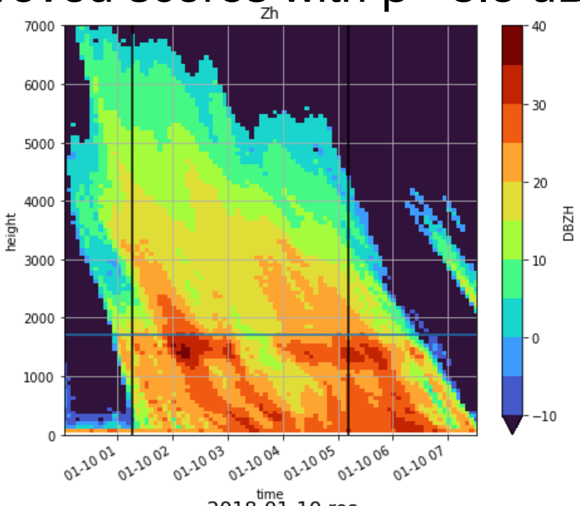
Event Variability

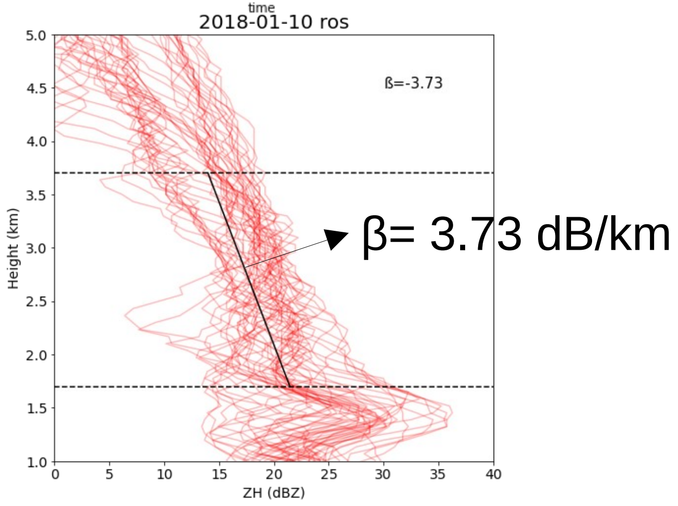
Improved scores with β= 5 dB/km





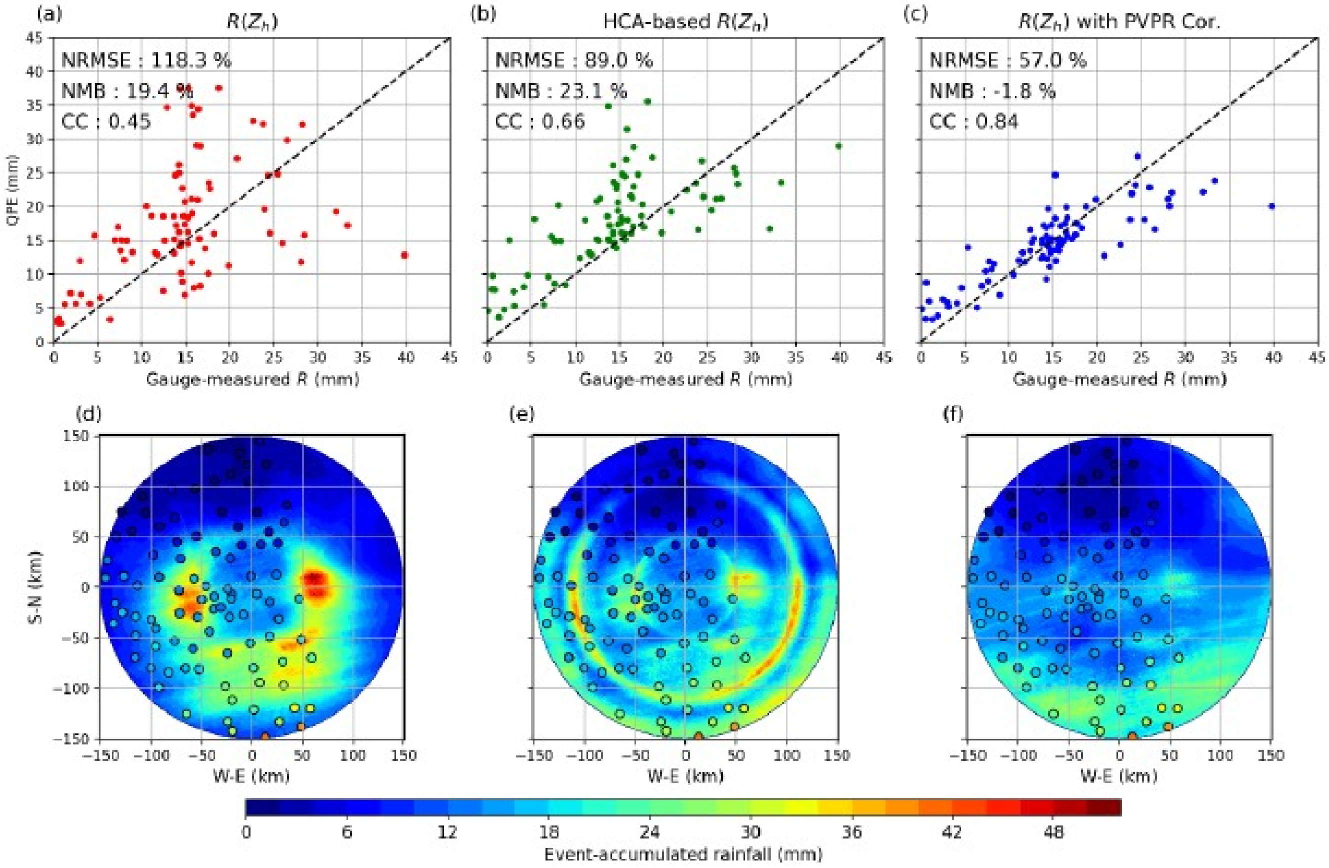
Improved scores with β= 3.5 dB/km





PVPR in Heterogeneous Rain

Prötzel radar 20180923



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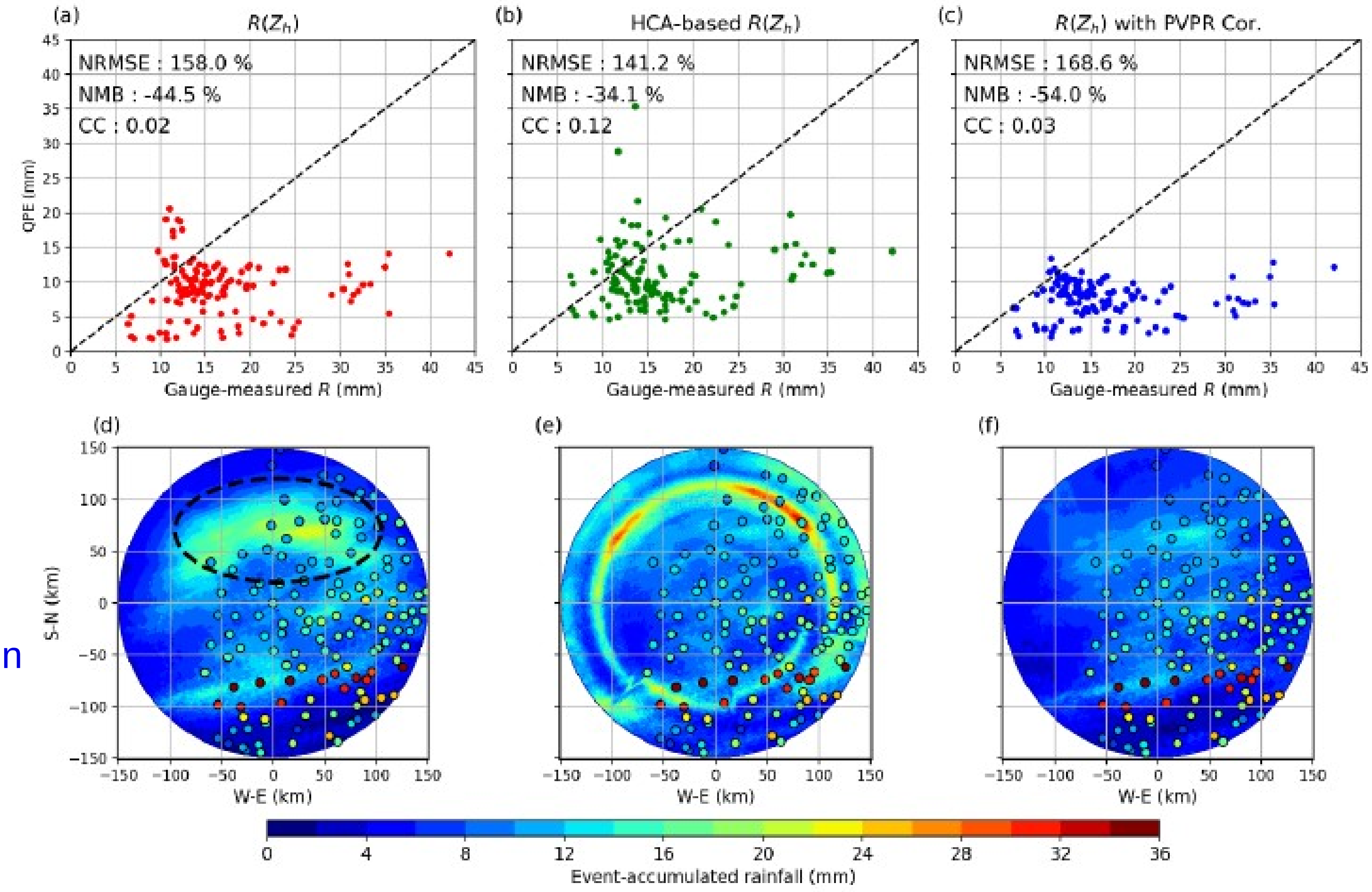
Ju-yu dissertation

PVPR in Heterogeneous Rain

Essen radar 20180923



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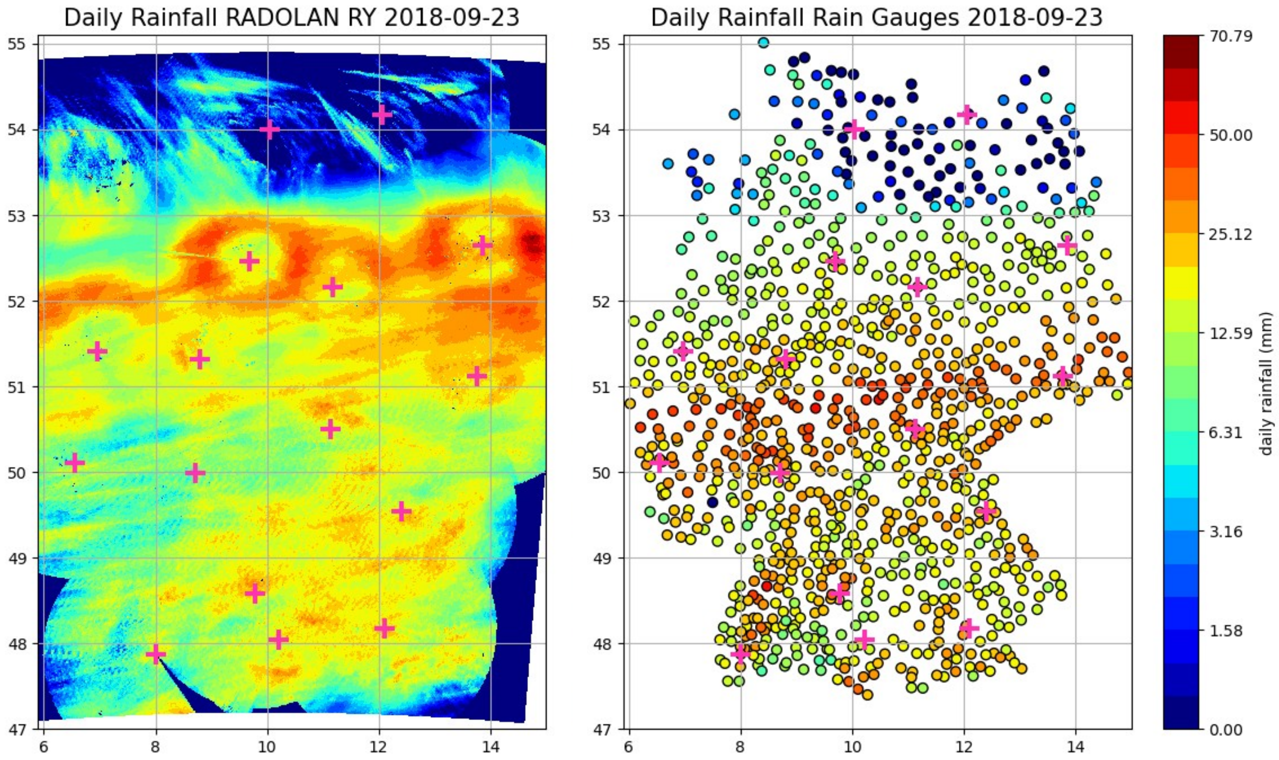
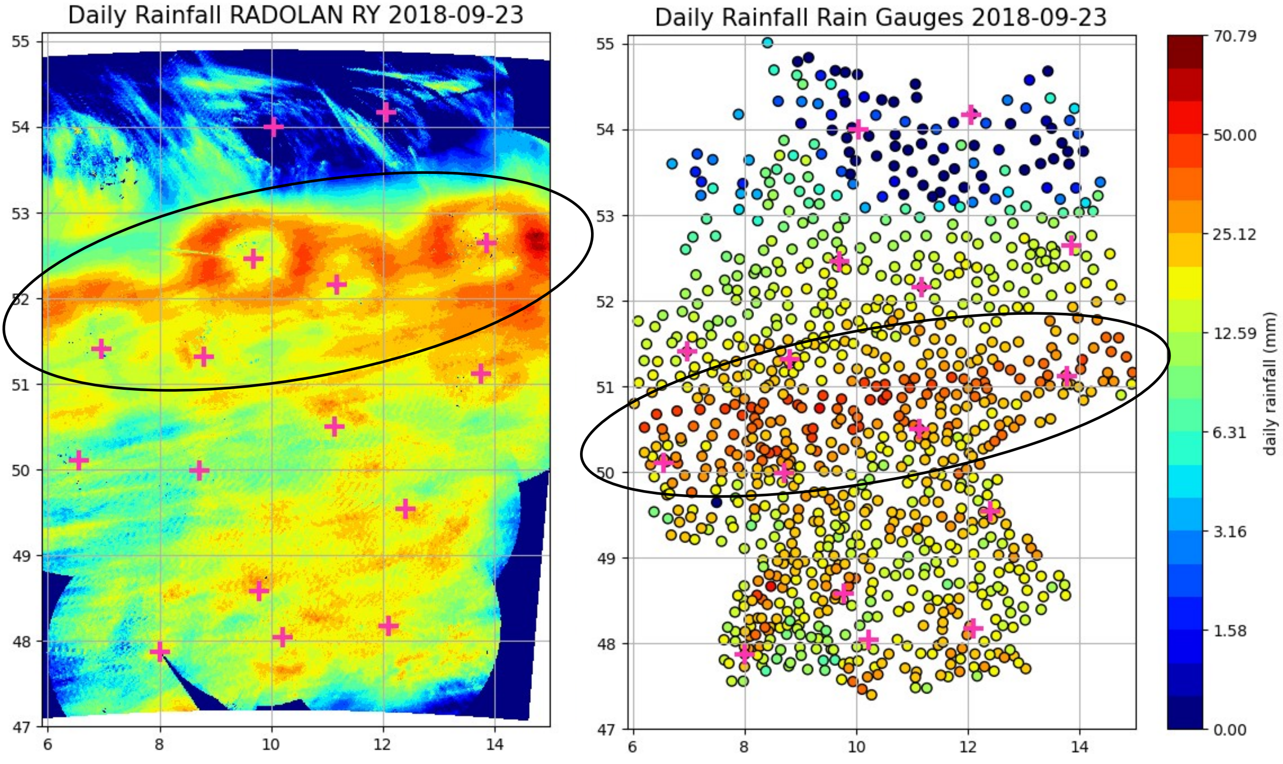
Ju-yu dissertation

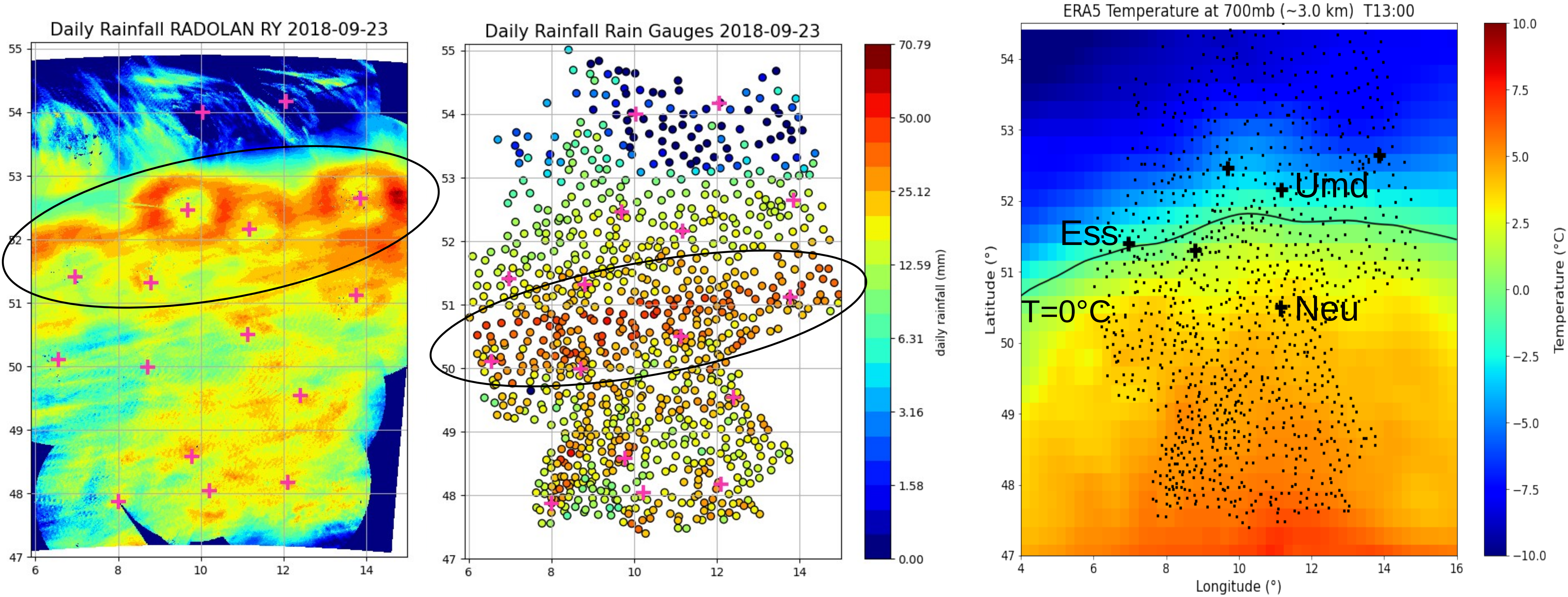
The 20180923 Event



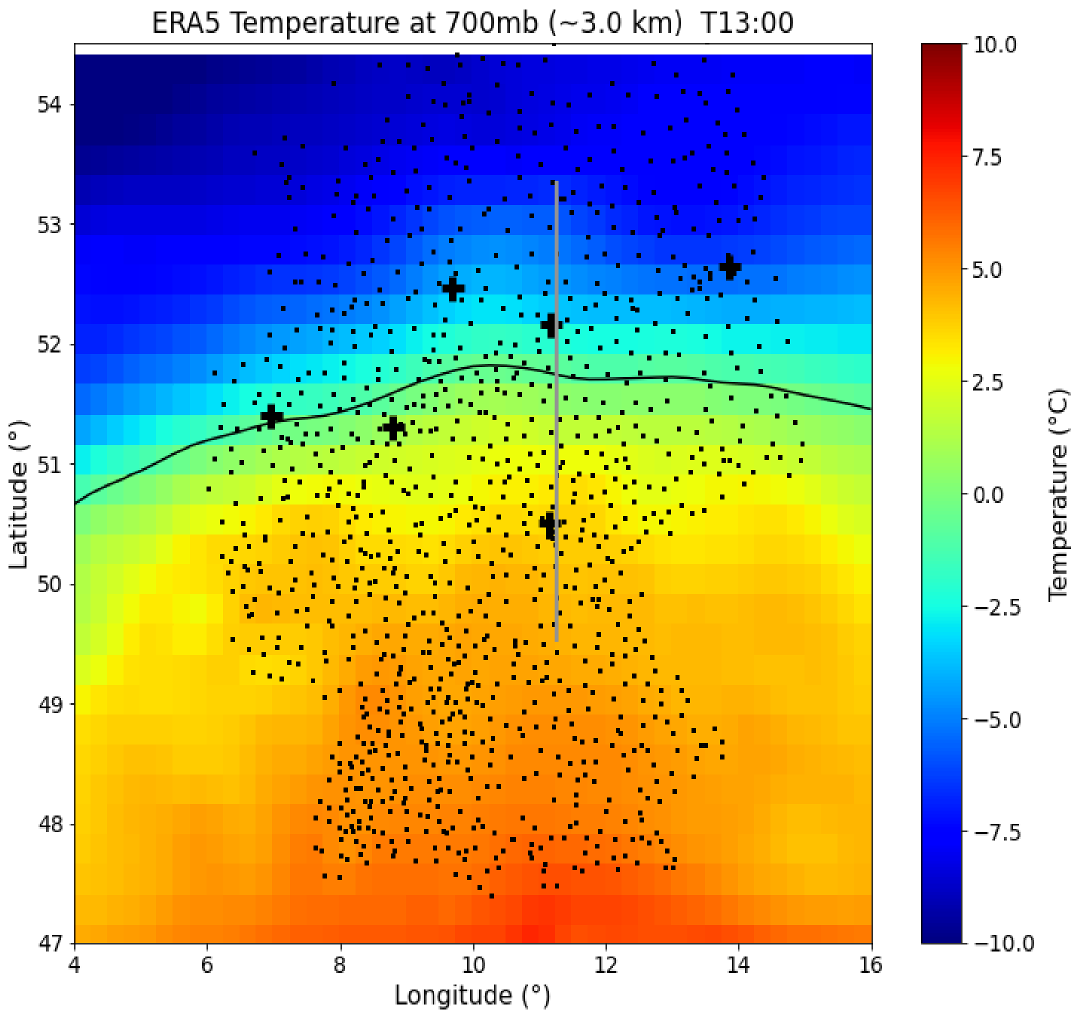
The 20180923 Event

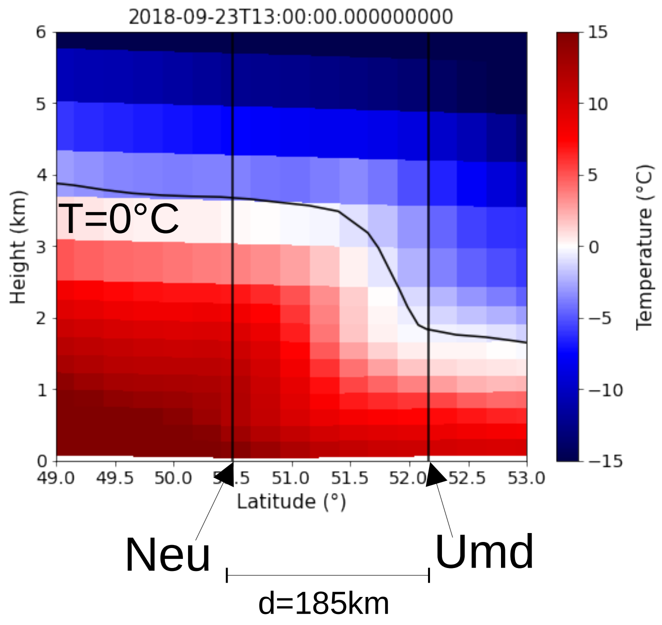


The 20180923 Event

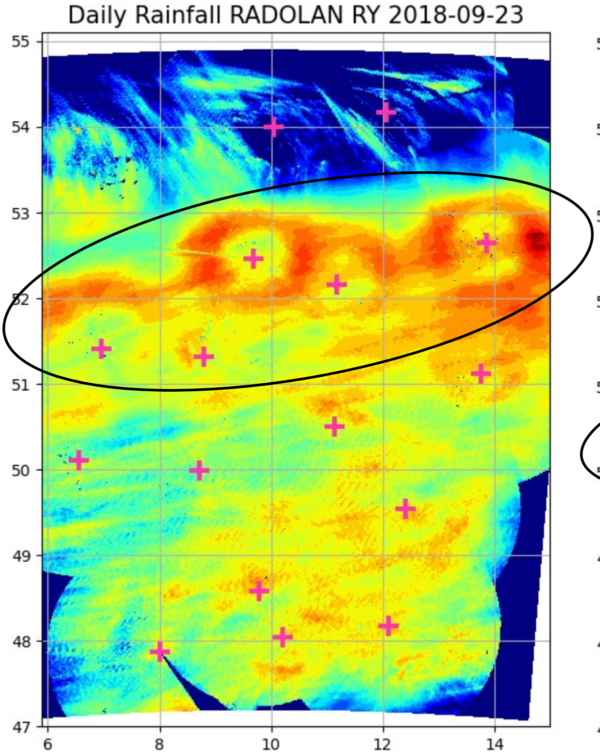


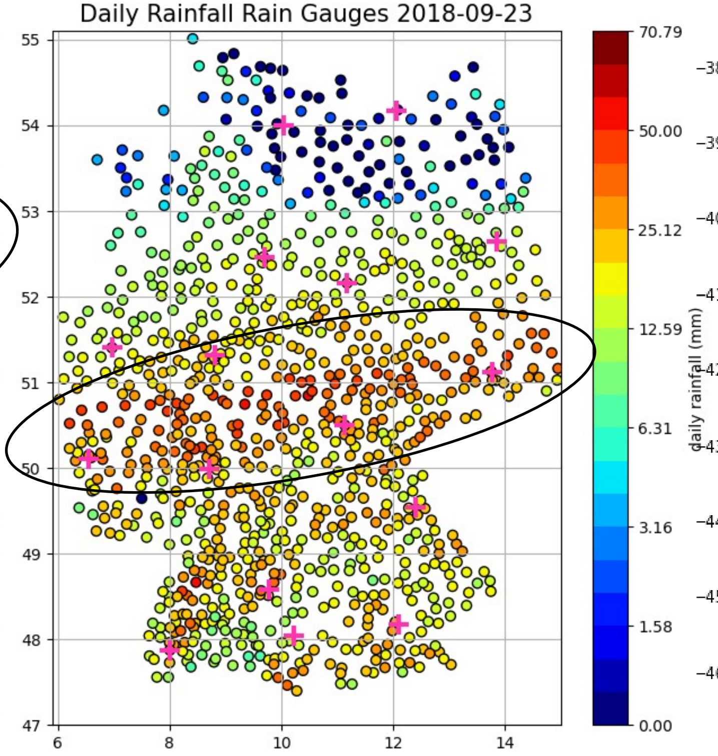
The 20180923 Event

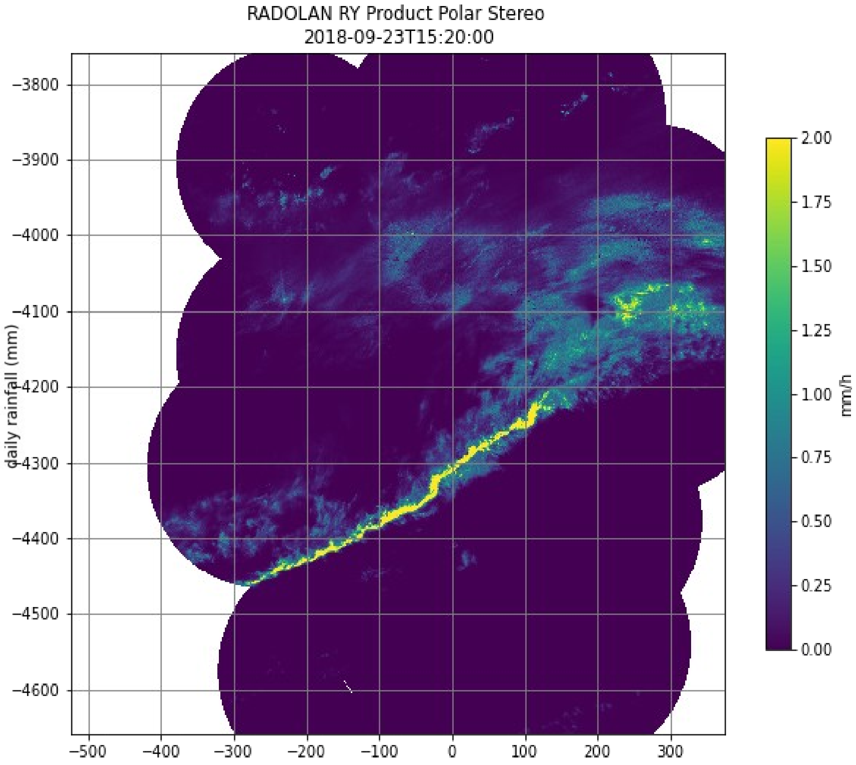




The 20180923 Event







The 20180923 Event

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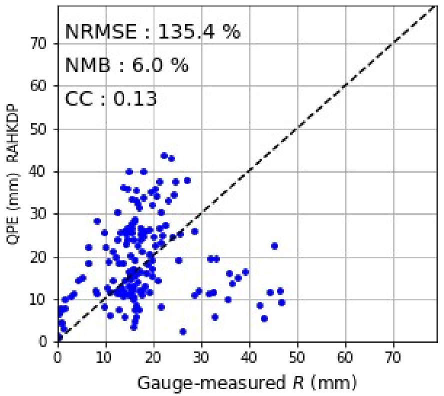
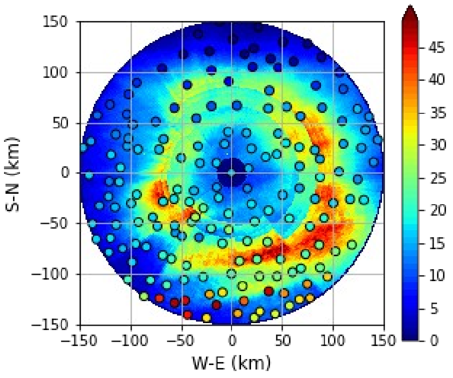
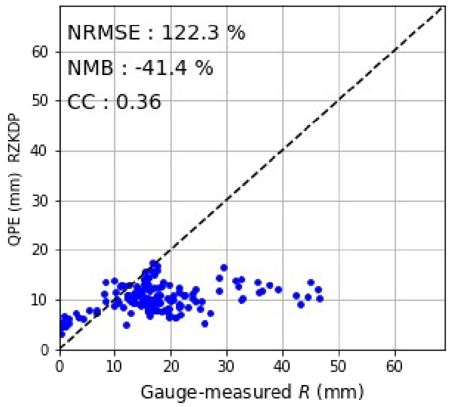
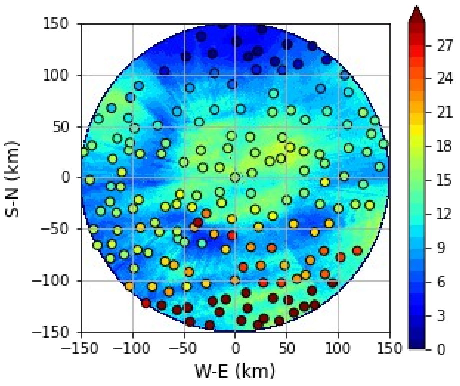
Default





Original PVPR

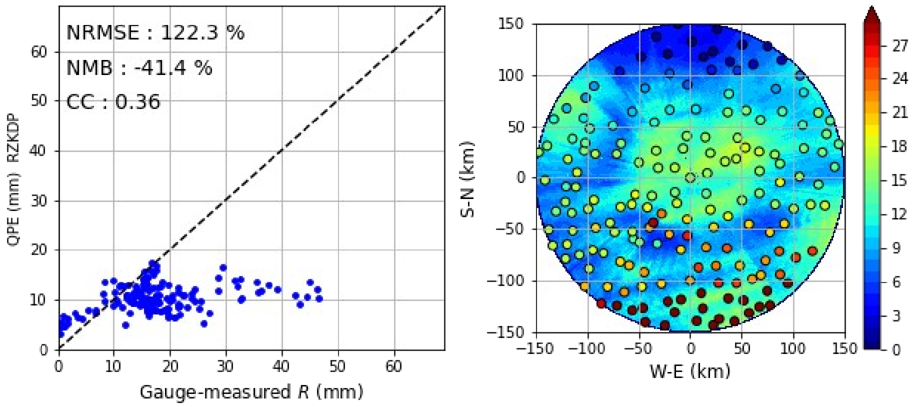




The 20180923 Event

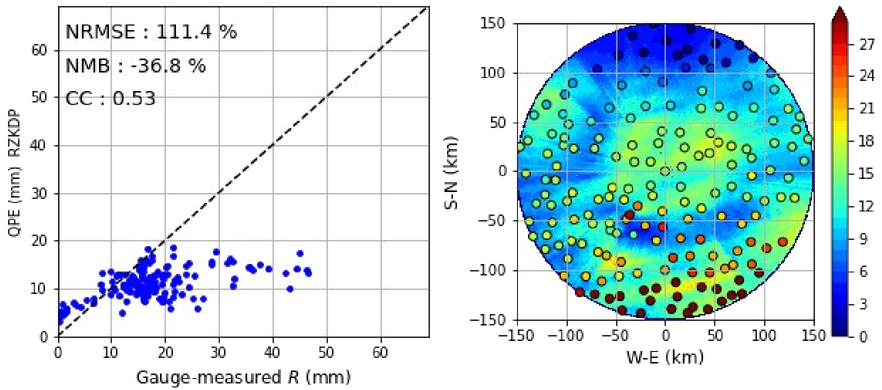
UMD 20180923

Original PVPR



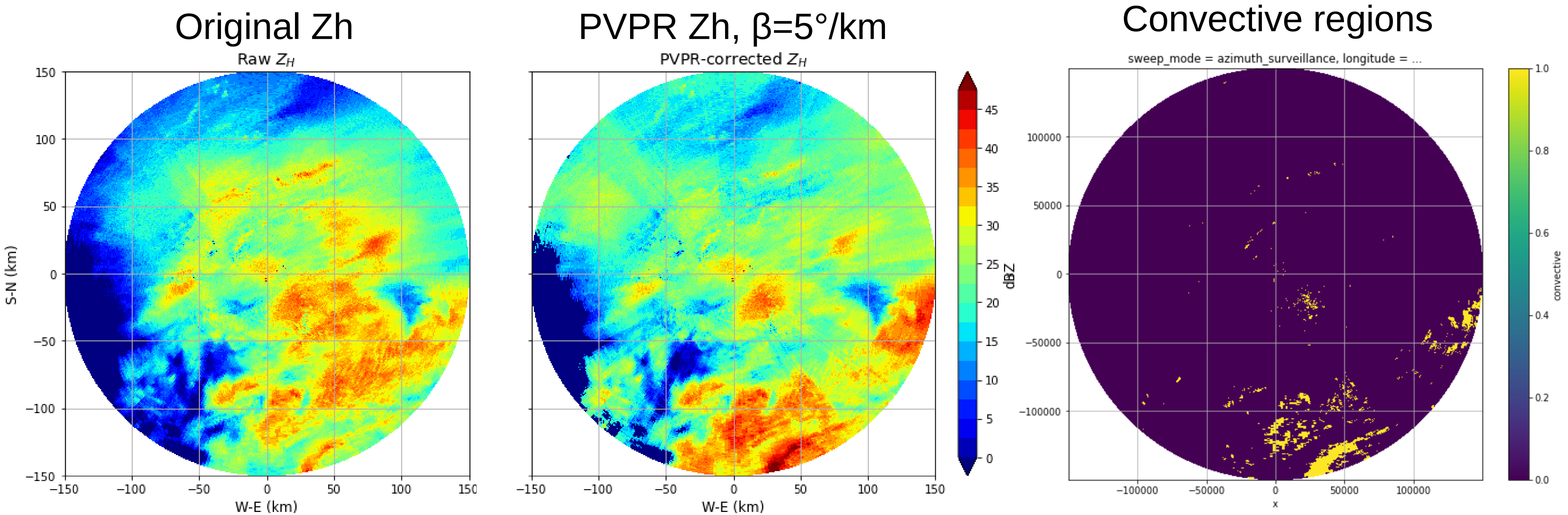
Dec. slope = 1.75

1N1_4N1_6N2



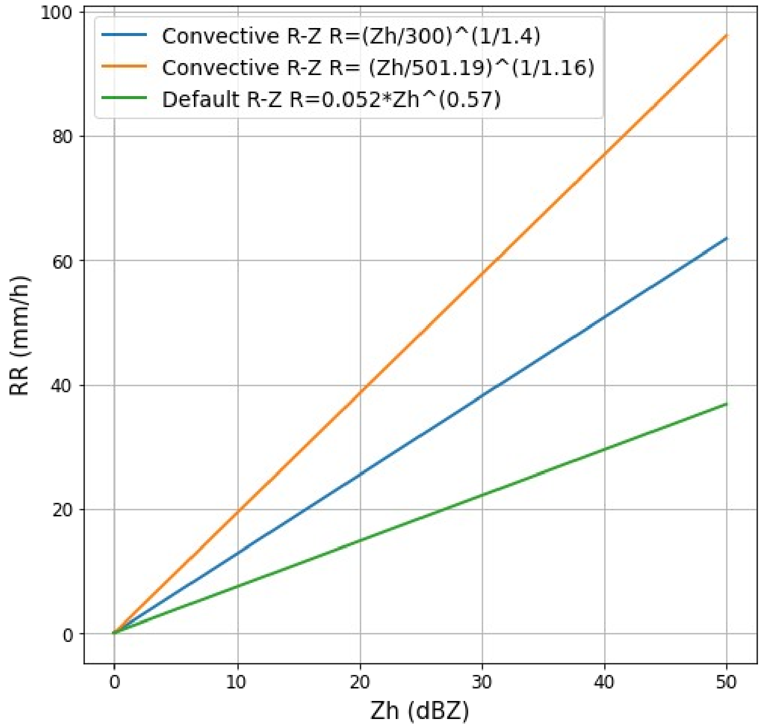
Identifying Convective regions

1520 UTC UMD 20180923



Powell, S. W., R. A. Houze, , and S. R. Brodzik, 2016: Rainfall-Type Categorization of Radar Echoes Using Polar Coordinate Reflectivity Data. J. Atmos. Oceanic Technol., 33, 523–538, https://doi.org/10.1175/JTECH-D-15-0135.1.

Convective Rainfall Calculation



Convective R-Z relationships:

Z = 300R^1.4 => R = 0.017 Zh ^ 0.714

Z = 501.19R^1.16 => R= 0.0047 Zh ^ 0.862

Default R-Z relationship:

R = 0.052 Zh ^ 0.57

Zeng, Z., Wang, D., Chen,Y., 2021: "An investigation of convective features and Z-R relationships for a local extreme precipitation event". *Atmospheric Research*,Vol. 250. https://doi.org/10.1016/j.atmosres.2020.105372

PVPR with Convective Rainfall

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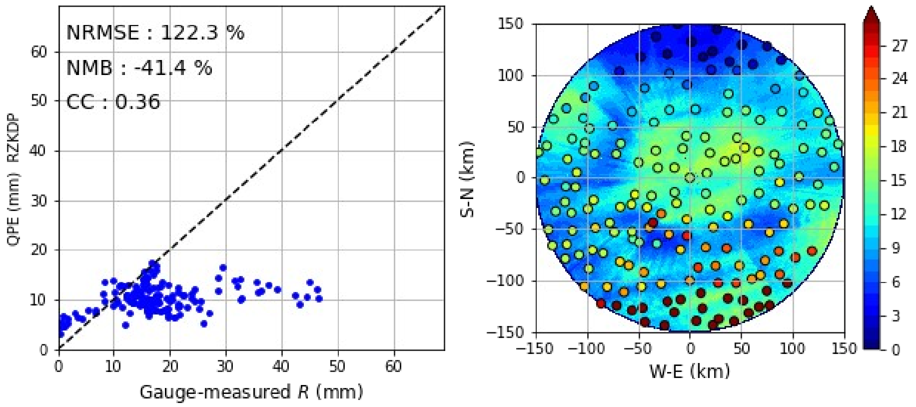
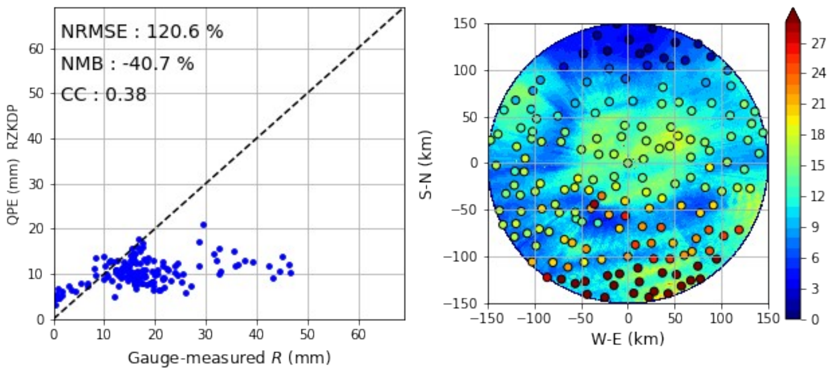
Original PVPR



PVPR + convection



PVPR with Convective Rainfall

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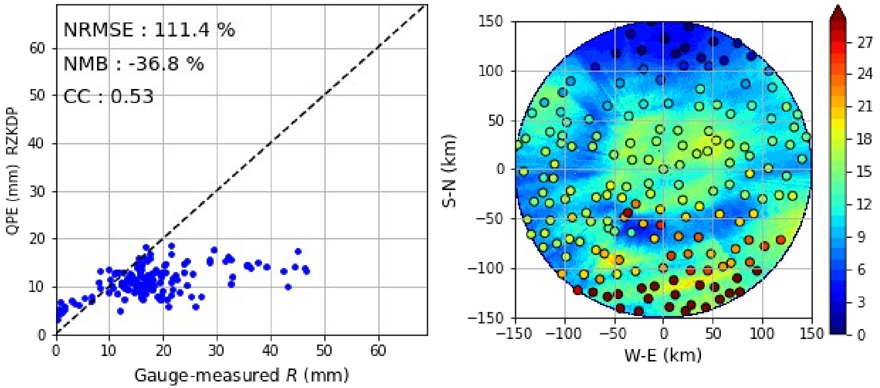
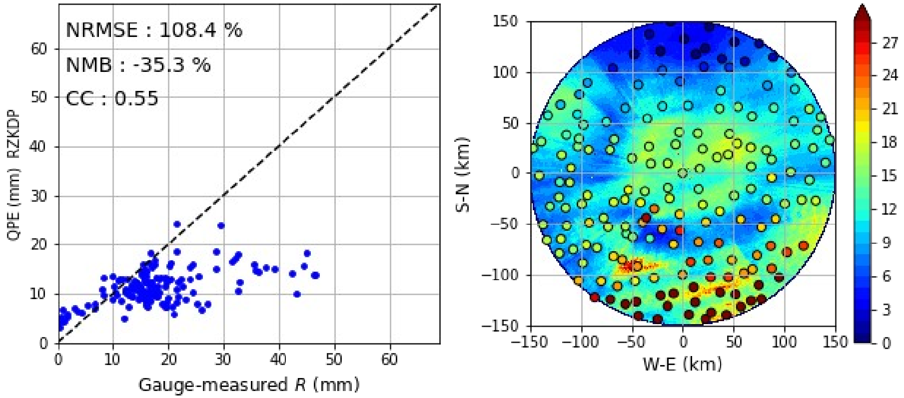
Dec. slope= 1.75

1N1_4N1_6N2



Dec. slope= 1.75 + Convection



PVPR with Convective Rainfall

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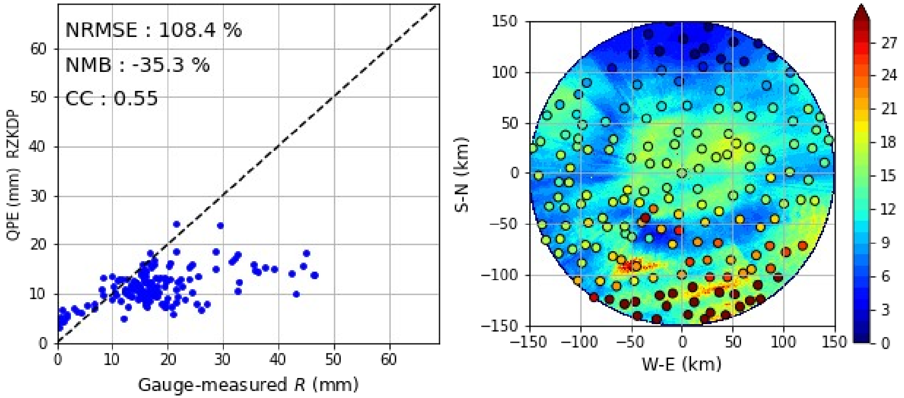
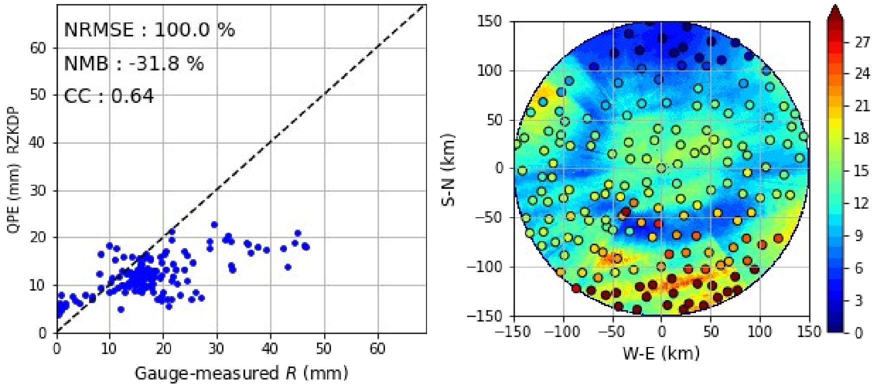
Dec. slope= 1.75 + Convection



β = 5°/km + Convection



PVPR with Convective Rainfall

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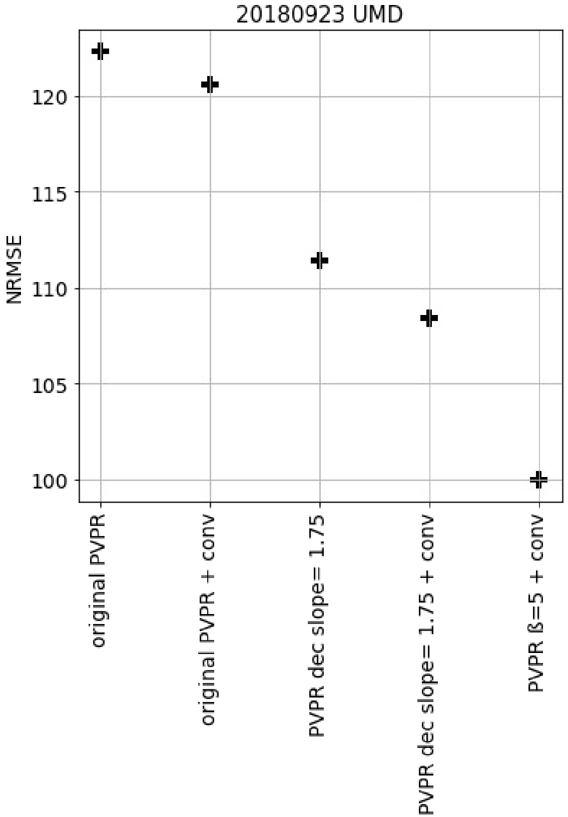
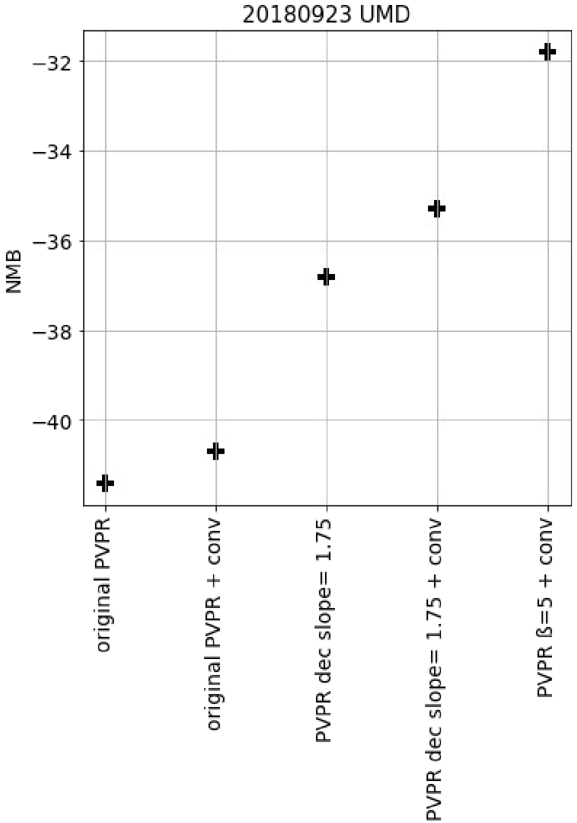
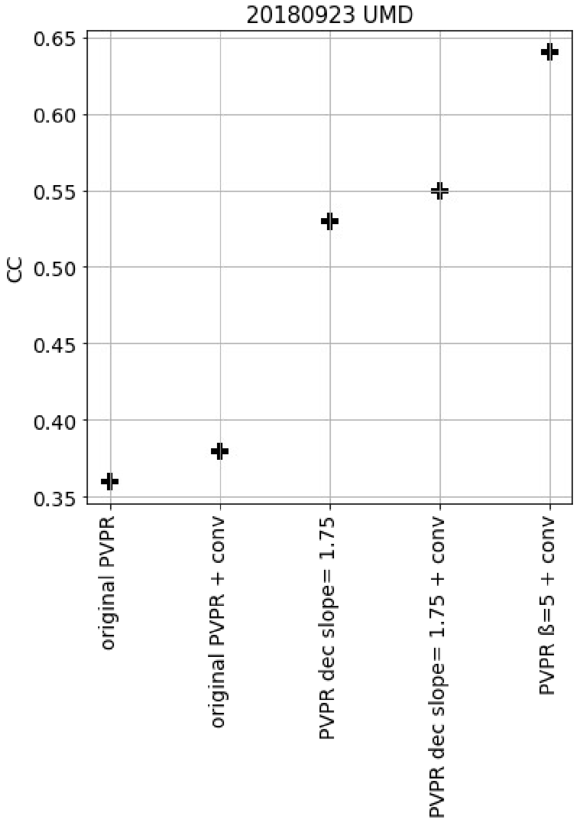
NRMSE



NMBias

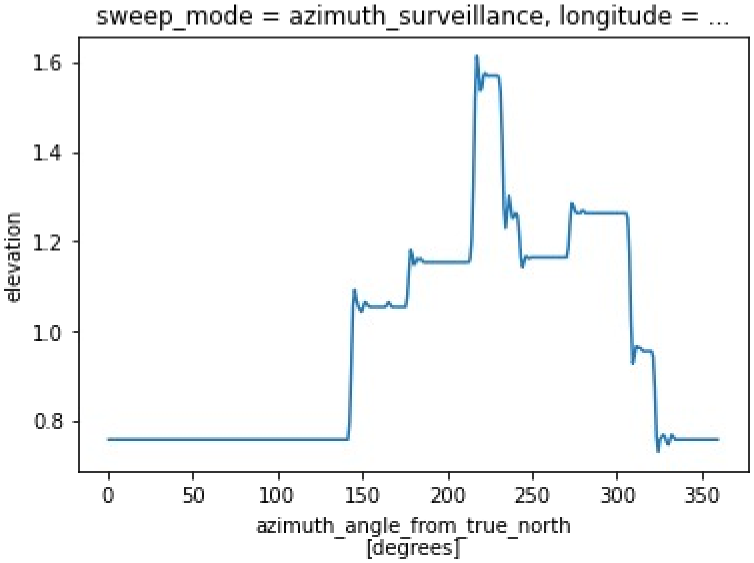


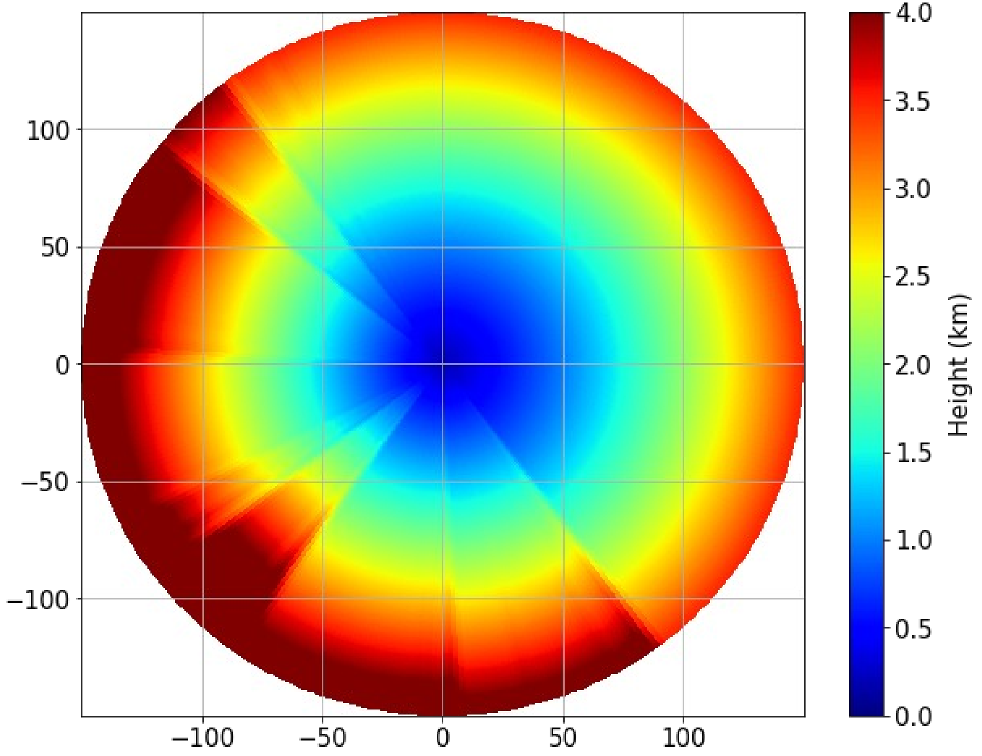
Correlation Coefficient

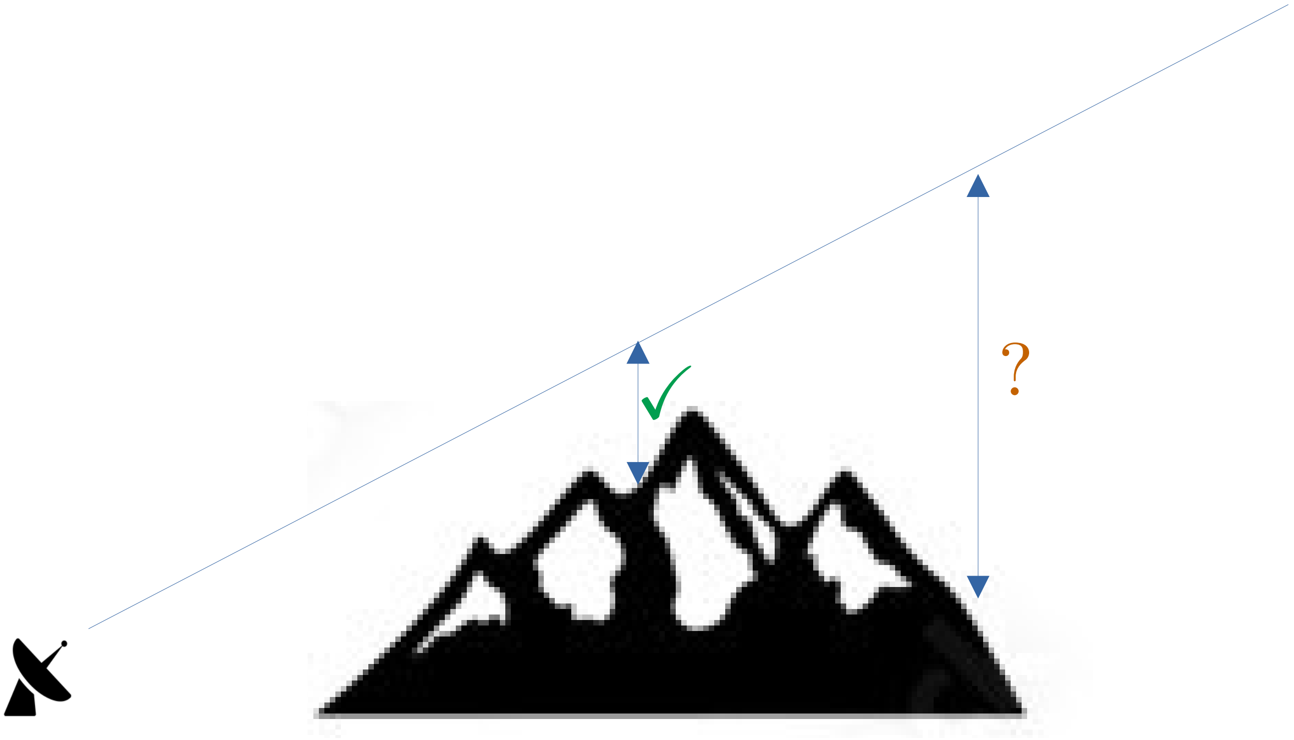


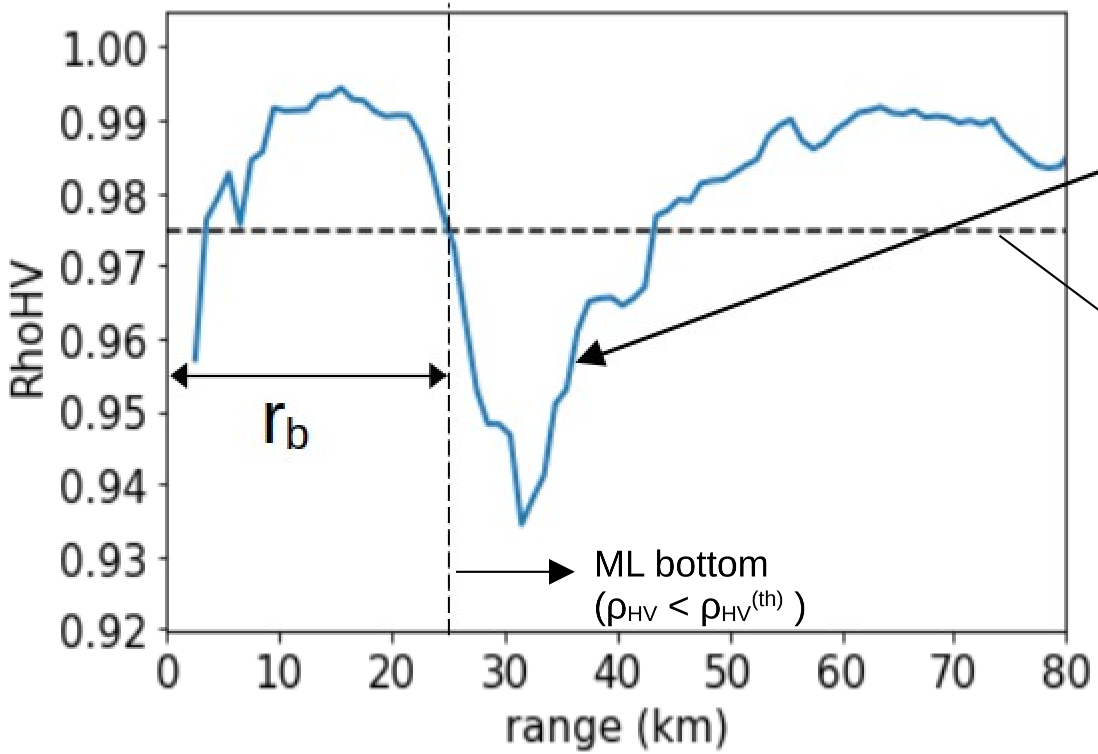
Summary

- PVPR technique shows clear improvements in QPE
  - Removing the effect of the ML
  - Improving the rainfall at far ranges
- Tests with parameters show that most impact comes from β and the decreasing slope of the dzcor
- Case by case adjustment of parameters for the best performance
- Including convection identification and a convective rainfall R-Z relation improves QPE estimation for this special case
- Parameters were tested independently from each other
  - Potential combinations to be tested in the future


sweep_mode = azimuth_surveillance, longitude = ...
1.6
1.4
1.2
1.0
0.8
elevation
0
50
100
150
200
250
300
350
azimuth_angle_from_true_north
[degrees]


100
50
0
−50
−100
−100
−50
0
50
100
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Height (km)





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

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