Status on the most recent QPE-products provided for RealPEP and outlook

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

WP-P1-2: Polarimetric QPE refinement by α segmentation

During the current ZPHI procedure to derive A,

① In case of hail contamination, A is biased in pure rain as the extra attenuation from hail cores is ignored.
→ **integration** should be reset for **each pure-rain segment**

② Although scan-wise α adjustment is immune to radar miscalibration, it is not ideal enough due to the **inhomogeneity** of the precipitation regimes within the scan.
→ **α** should be optimized **segment-wise** via its dependence on ZDR

$$\langle \alpha \rangle = \frac{\int Z^{b}(r)dr}{\int \frac{Z^{b}(r)}{\alpha[Z_{DR}(r)]}dr}$$

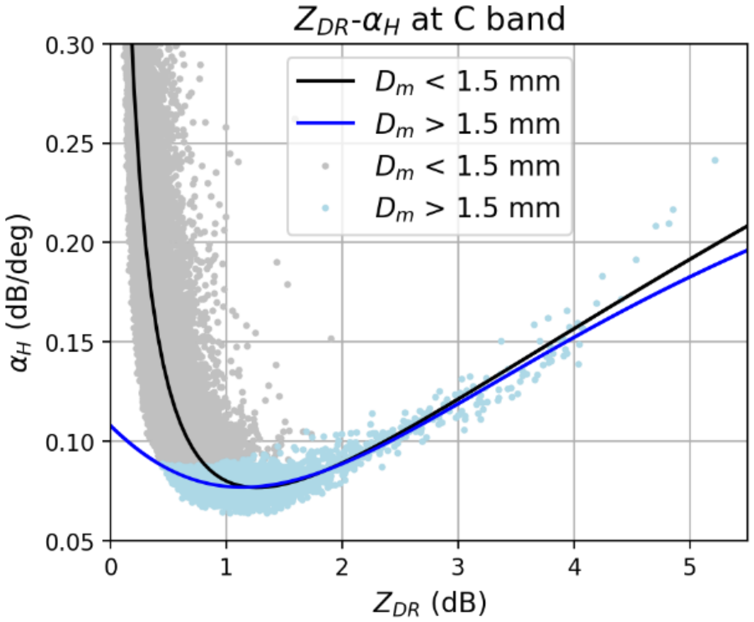
← $Z^{att.cor.}$

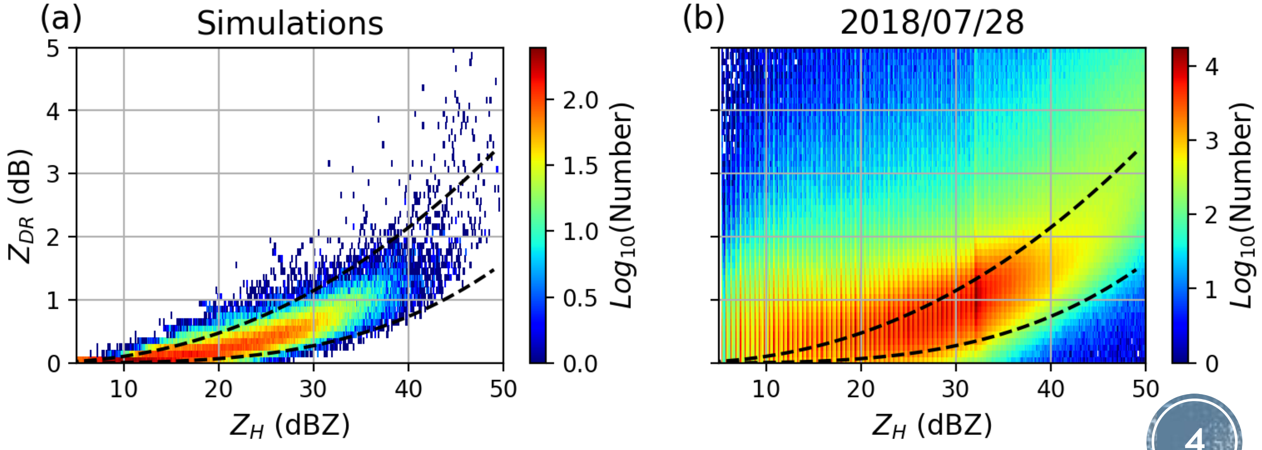
← $Z_{DR}^{att.cor.}$

WP-P1-2: Polarimetric QPE refinement by α segmentation

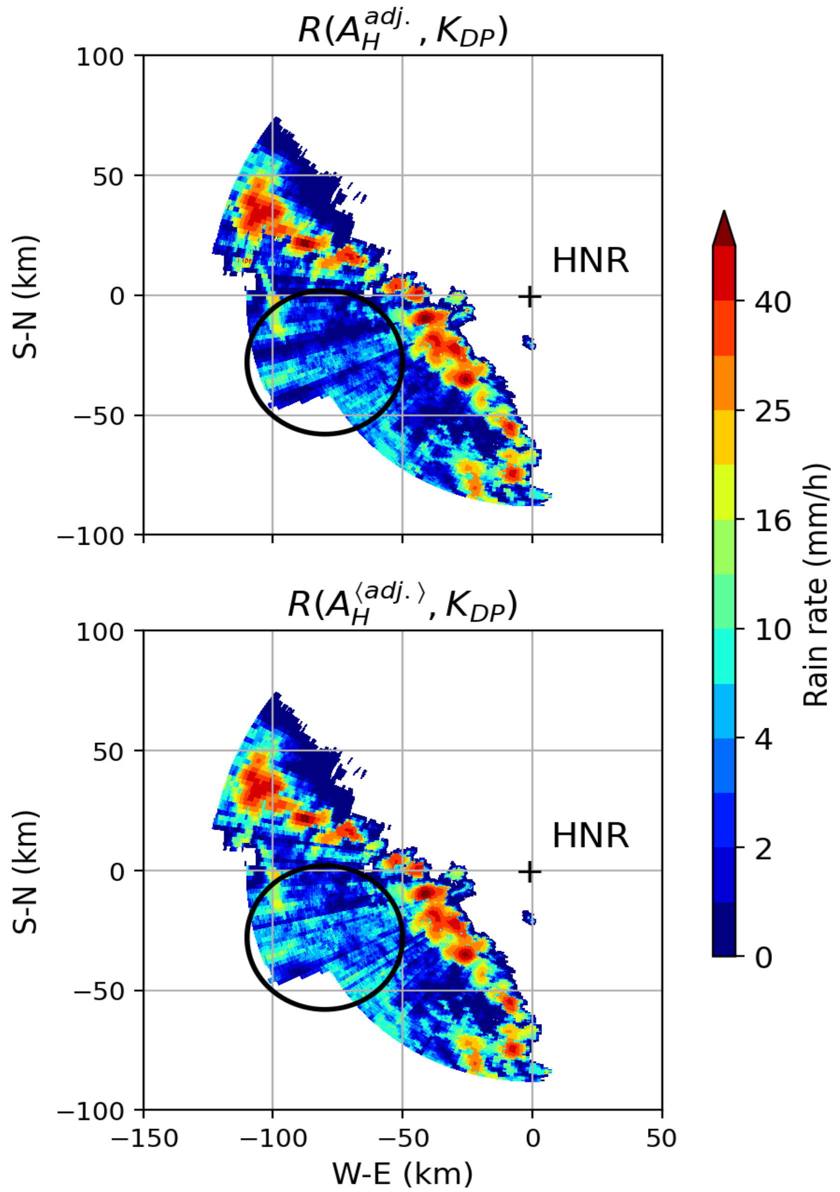
As shown in the last meeting, QPE errors increase when segment-wise α is applied in convective rain, thus

- Two $\alpha(Z_{DR})$ relations are used depending on $\boldsymbol{D_m}$.
- $\langle\alpha\rangle$ and segment-wise integration is computed/performed only within the segment where Z_H is below **40** dBZ.
- $\Delta\Phi_{DP}$ is replaced with $\boldsymbol{\Delta\Phi_{DP}^{cal.}}$ when it is either two times larger or half times lower than $\Delta\Phi_{DP}^{cal.}$.
- Two boundaries are used to **constrain** $\boldsymbol{Z_{DR}}$ observations.



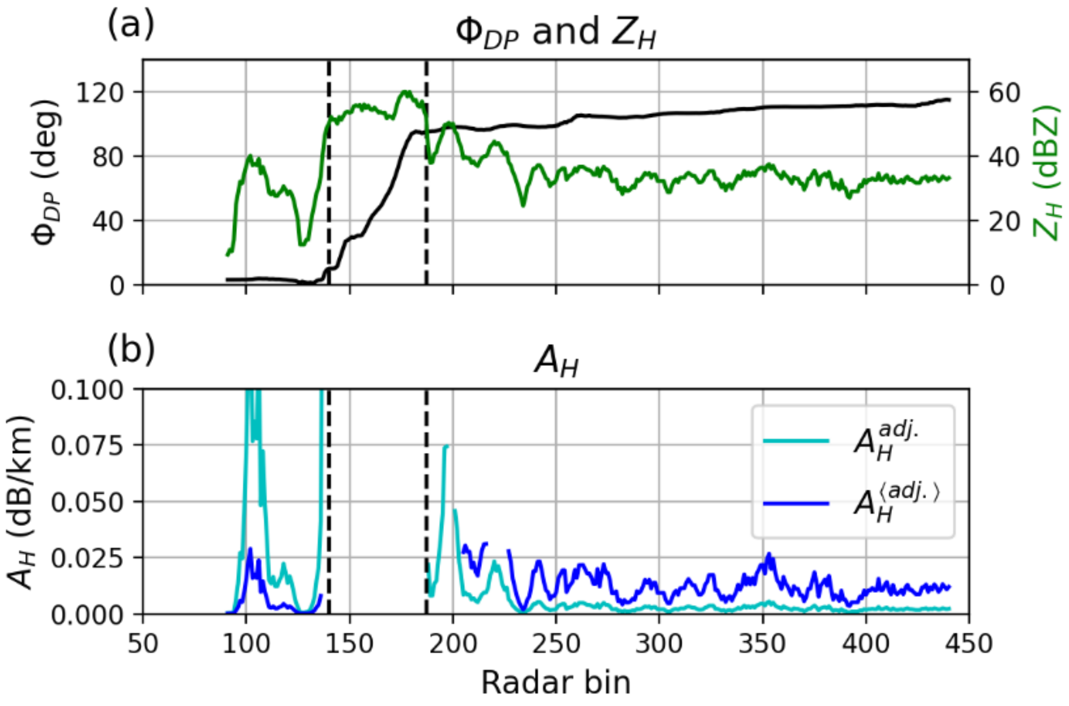


WP-P1-2: Polarimetric QPE refinement by α segmentation



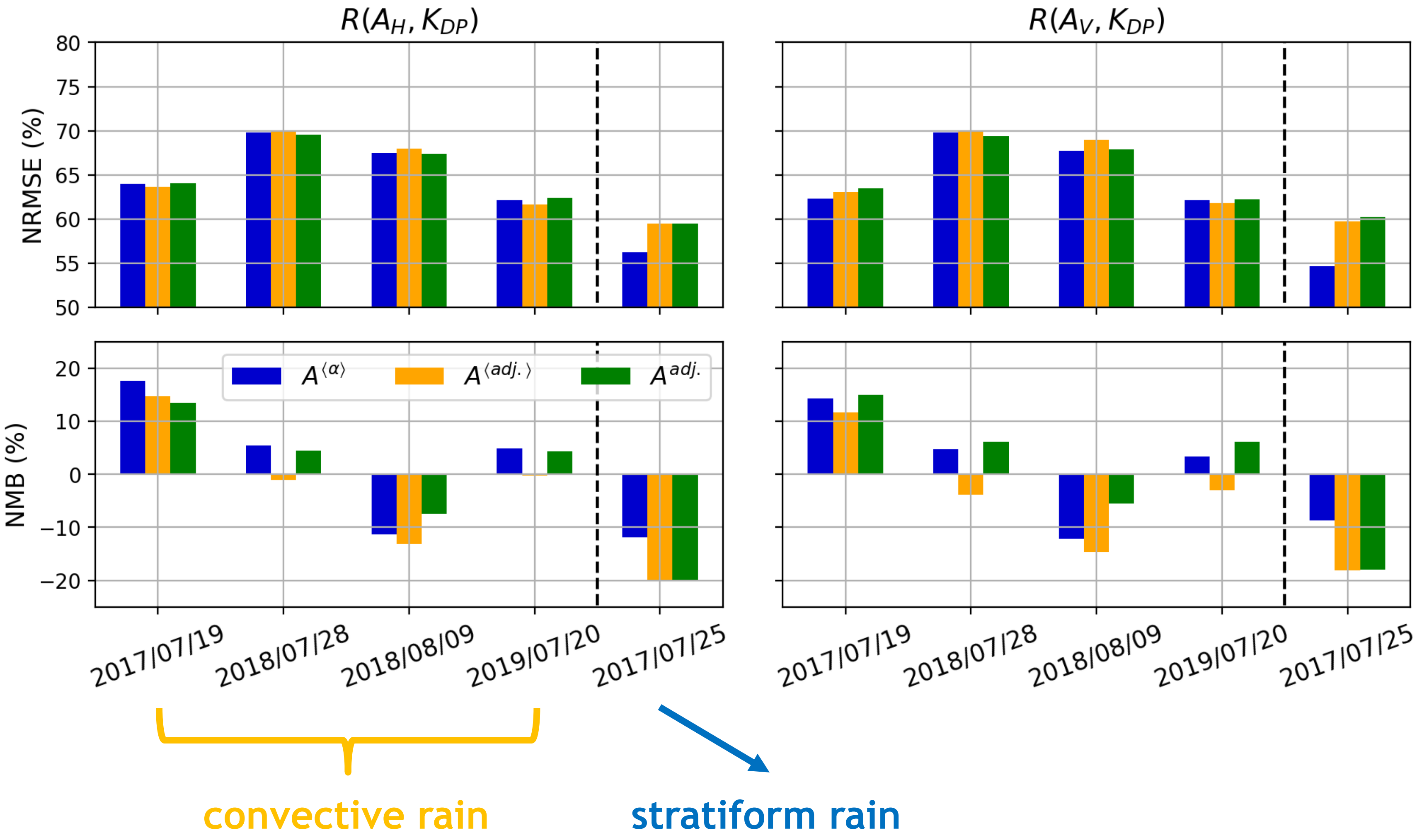
$adj.$ = scan-wise α and ray-wise integration

$\langle adj.\rangle$ = scan-wise α and segment-wise integration



- $R(A_H^{\langle adj.\rangle}, K_{DP})$ generates less biased rays.
- $A_H^{\langle adj.\rangle}$ rectifies the overestimated values of $A_H^{adj.}$ before and underestimated values after the HS.

WP-P1-2: Polarimetric QPE refinement by α segmentation



Convective rain

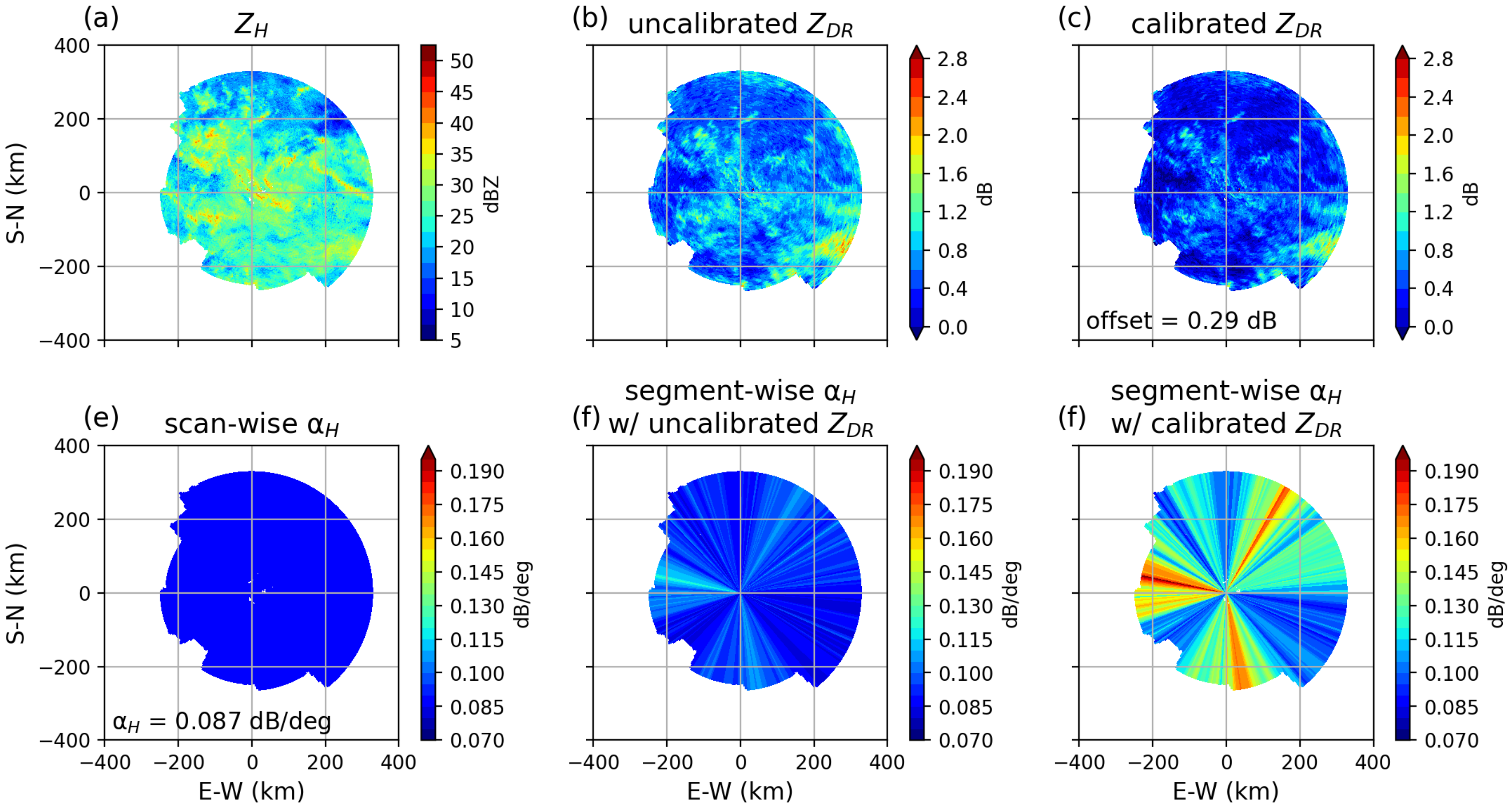
- Neither $\langle\alpha\rangle$ nor the segment-wise integration can reliably enhance the accuracy of A and thus $R(A)$.
- Up to **40% of noisy $\Delta\Phi_{DP}$** within the segments are **substituted**.

Stratiform rain

- $R\left(A^{\langle\alpha\rangle}, K_{DP}\right)$ yields the lowest errors owing to **reduced uncertainties in attenuation** and the **decreased need** for **segment-wise integration**.

WP-P1-2: Polarimetric QPE refinement by α segmentation

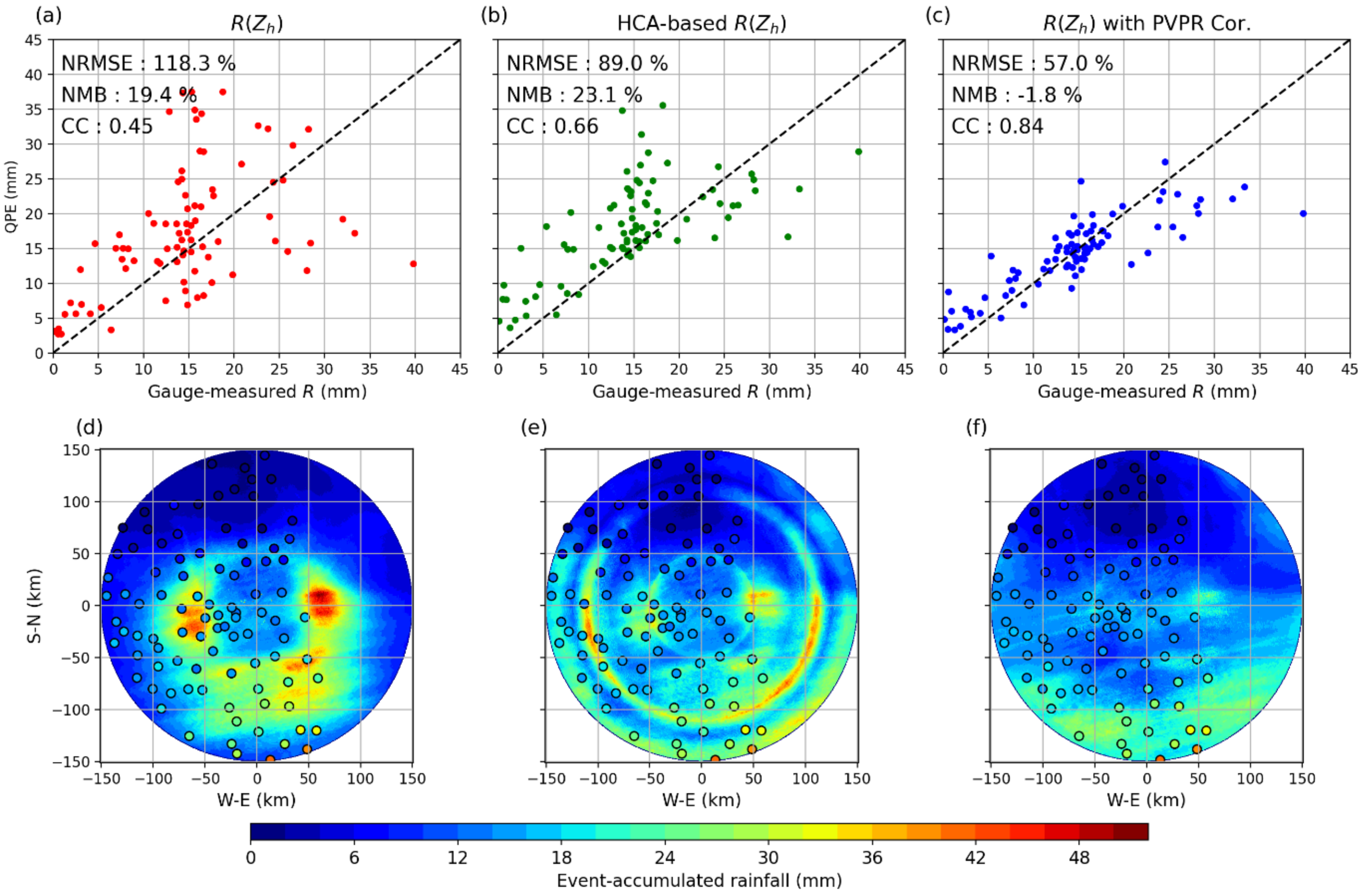
In stratiform rain, $R(A^{\langle\alpha\rangle}, K_{DP})$ performance heavily depends on the accuracy of Z_{DR} calibration



Recommendation: use a **rain-type classifier on the entire scan** and optimize α values individually for each hydrometeor type through **Z_{DR} slopes**.

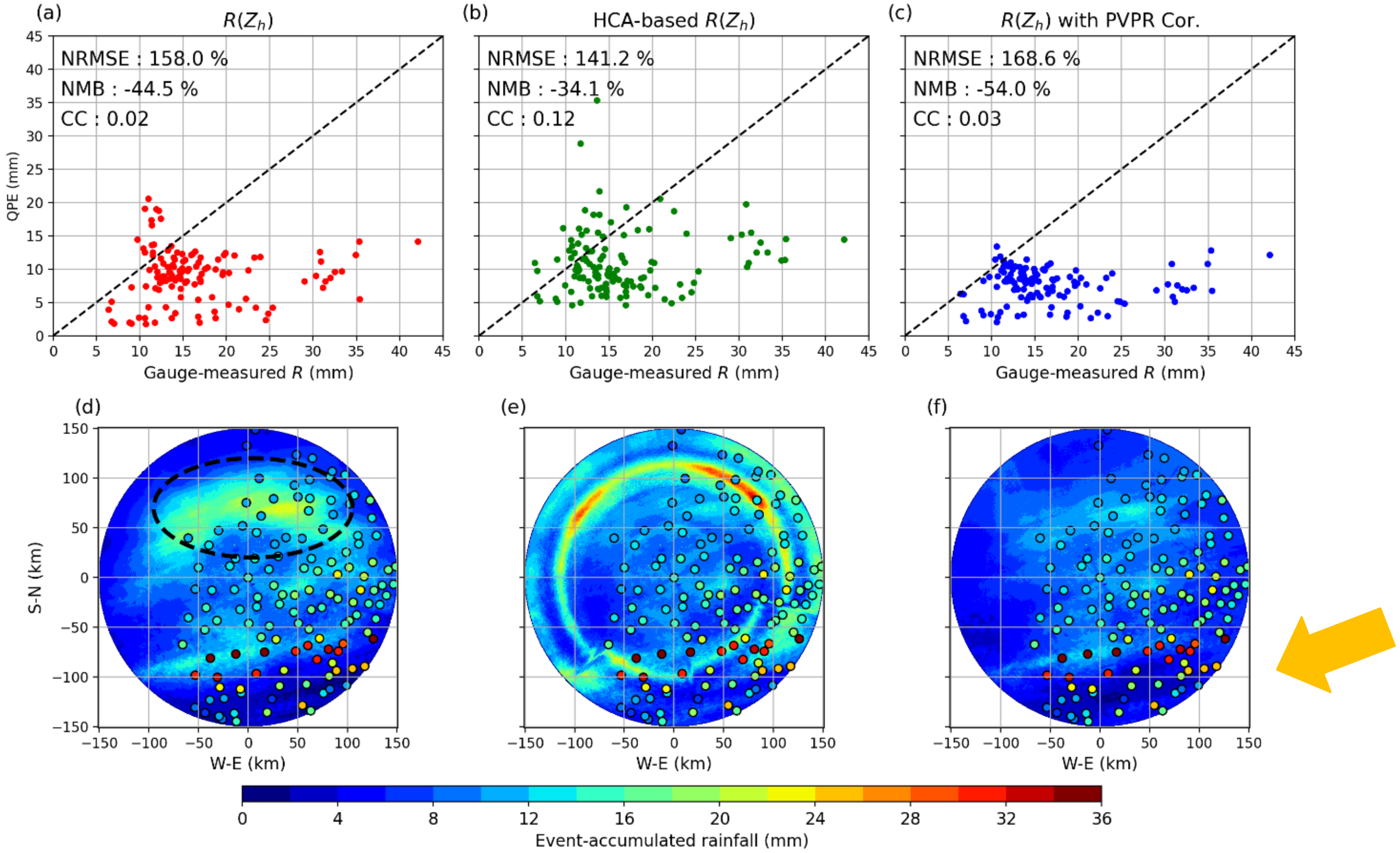
WP-P1-3: Polarimetric QPE in snow and mixed-phase regions

Polarimetric VPR (PVPR) in pure uniform stratiform rain



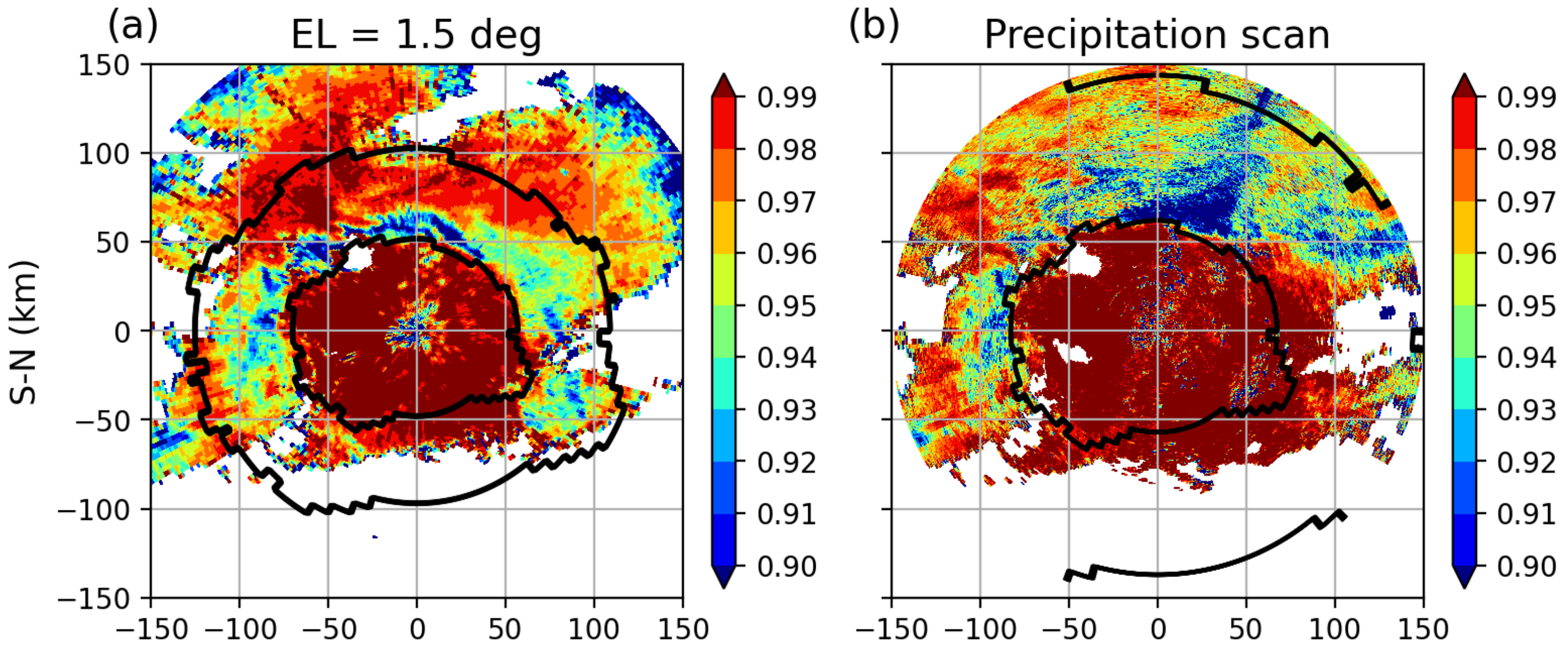
Polarimetric VPR (PVPR) in heterogeneous rain

when the current MLDA cannot accurately estimate the BB-contaminated areas



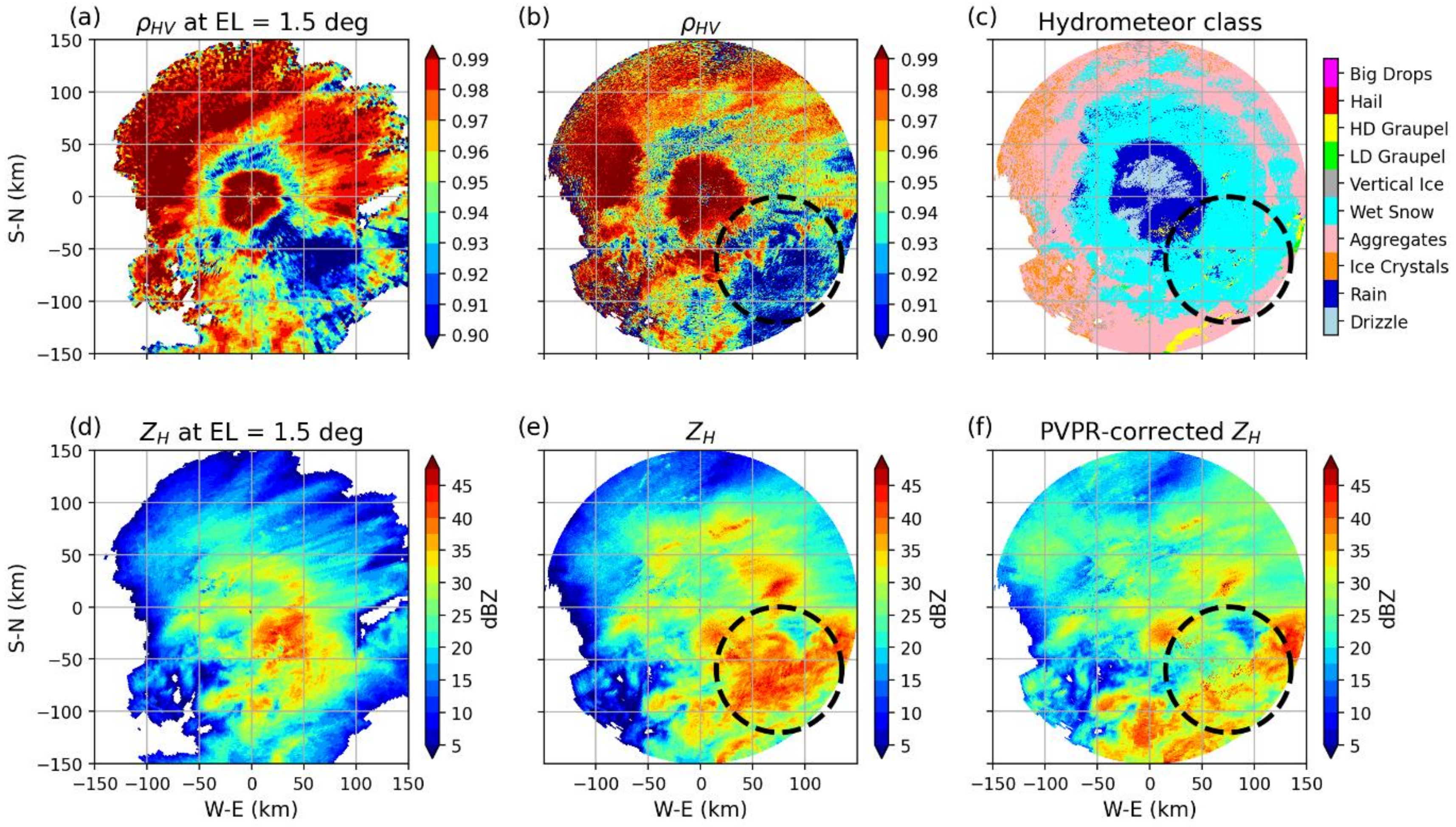
Polarimetric VPR (PVPR) in heterogeneous rain

① the height of the ML significantly varies with azimuth



Polarimetric VPR (PVPR) in heterogeneous rain

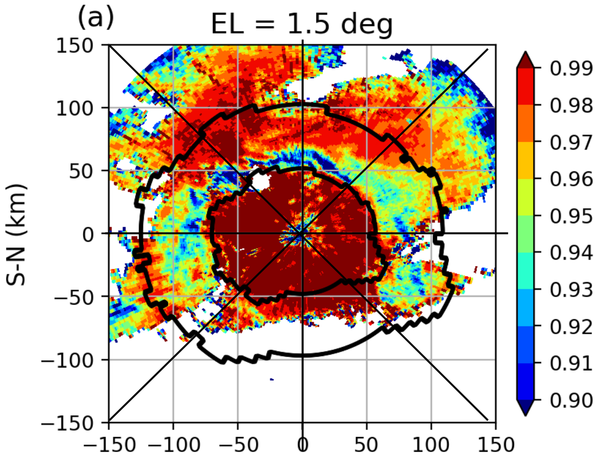
② when a convective cell penetrates the estimated BB zone



WP-P1-3: Polarimetric QPE in snow and mixed-phase regions

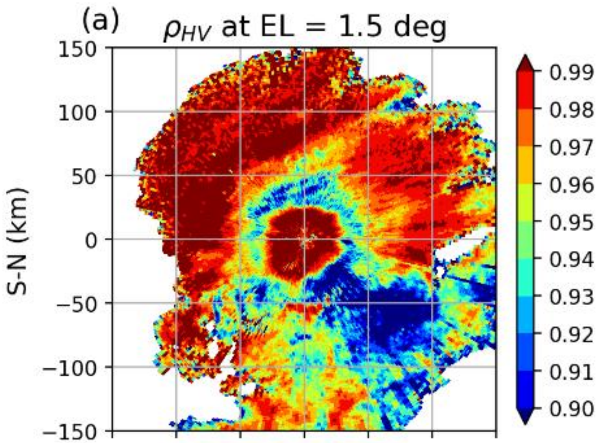
Identified challenges and potential solutions

① the height of the ML significantly varies with azimuth



- ✓ Automatic detection of ML performed sectorwise, using sector-QVPs
- ✓ Application of the PVPR correction separately for each sector
- ✓ Decision on sector size needs testing

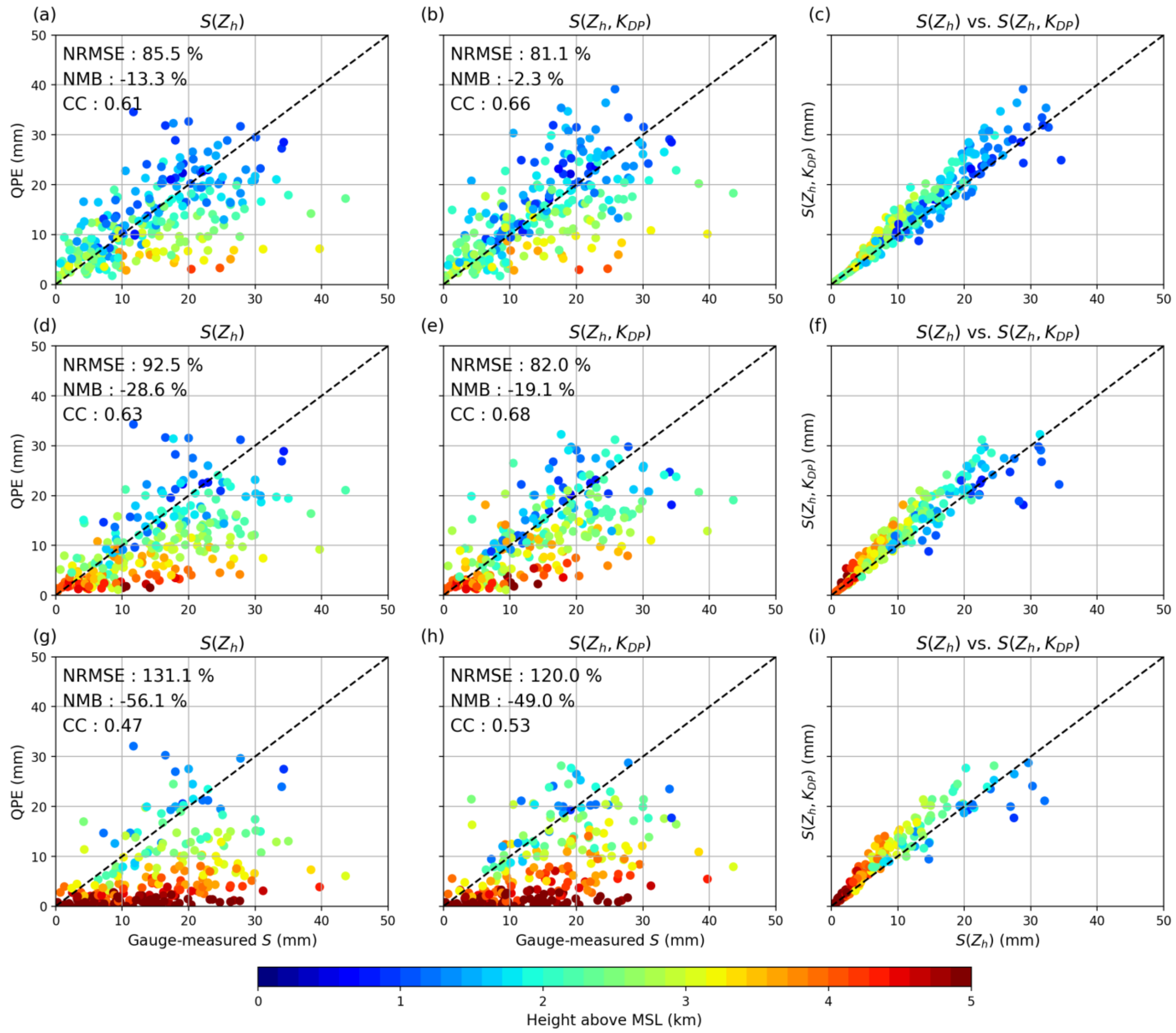
② when a convective cell penetrates the estimated BB zone



- ■ Convection: decrease in ρ_{HV}, increase in Z_H and Z_{DR} similar to ML signature in the beam
- ✓ Identification of convective cores
  - → Searching for the signatures of convection well above the ML at higher elevations
  - → Easily distinguished from the snow outside the convective region
- ✓ PVPR correction not applied to sector affected by convection

WP-P1-3: Polarimetric QPE in snow and mixed-phase regions

Improve retrievals for snowfall intensity



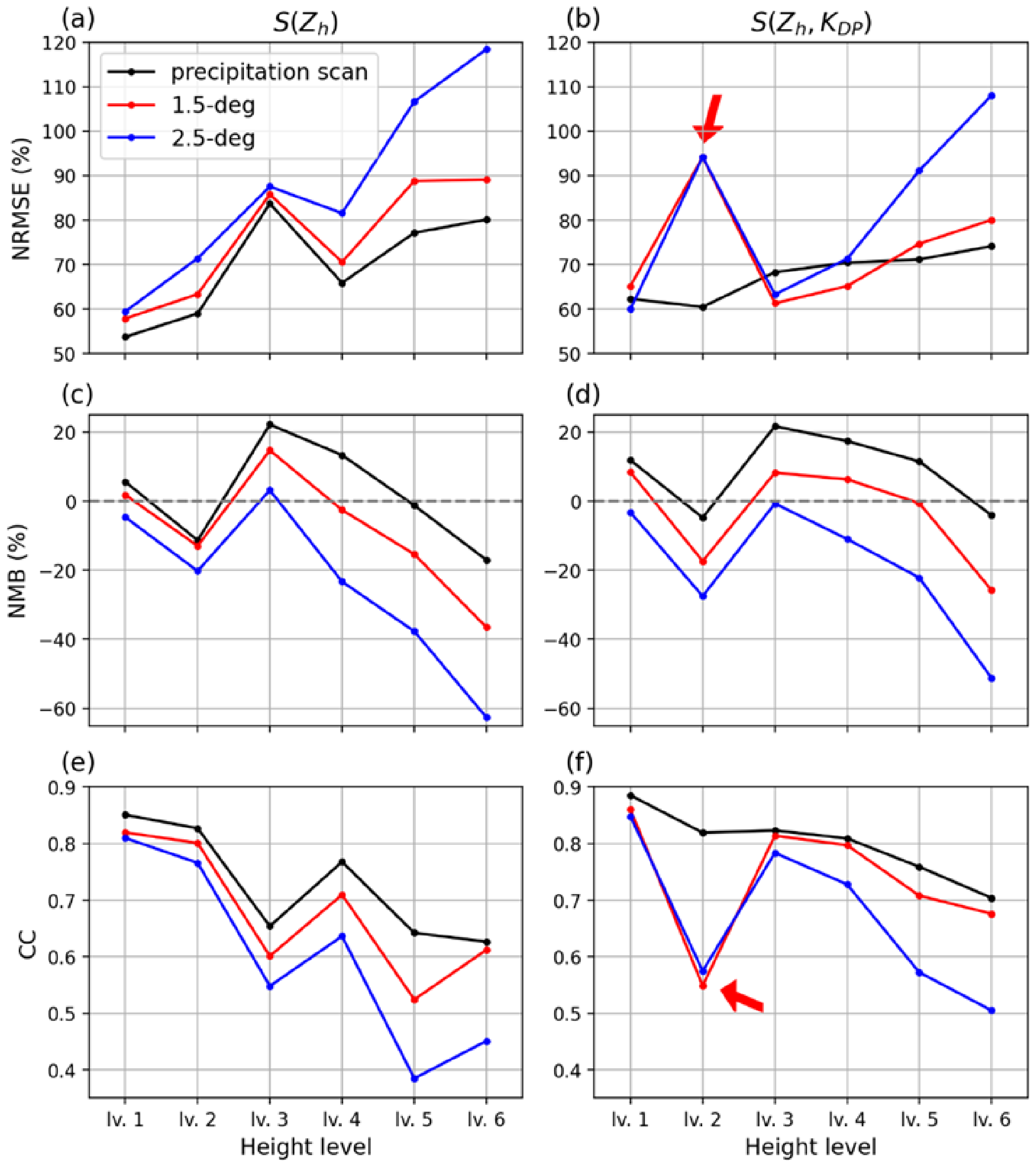
$$S(Z_h, K_{DP}) = \frac{27.9\times10^{-3}}{[F_o(L_a - L_b)]^{0.615}} \left(\frac{P_o}{P}\right)^{0.5} Z_h^{0.33} (K_{DP}\lambda)^{0.615}.$$

- $S(Z_h, K_{DP})$ outperforms $S(Z_h)$
- Snowfall is underestimated when radar observations are taken above 2.5 km height as a result of **beam-broadening effects**

  → more **pronounced for $S(Z_h)$** at all elevation angles.
- At 1.5/2.5-deg angles, **$S(Z_h, K_{DP})$ at lower altitudes** yields **smaller** snowfall sums compared to $S(Z_h)$.

WP-P1-3: Polarimetric QPE in snow and mixed-phase regions

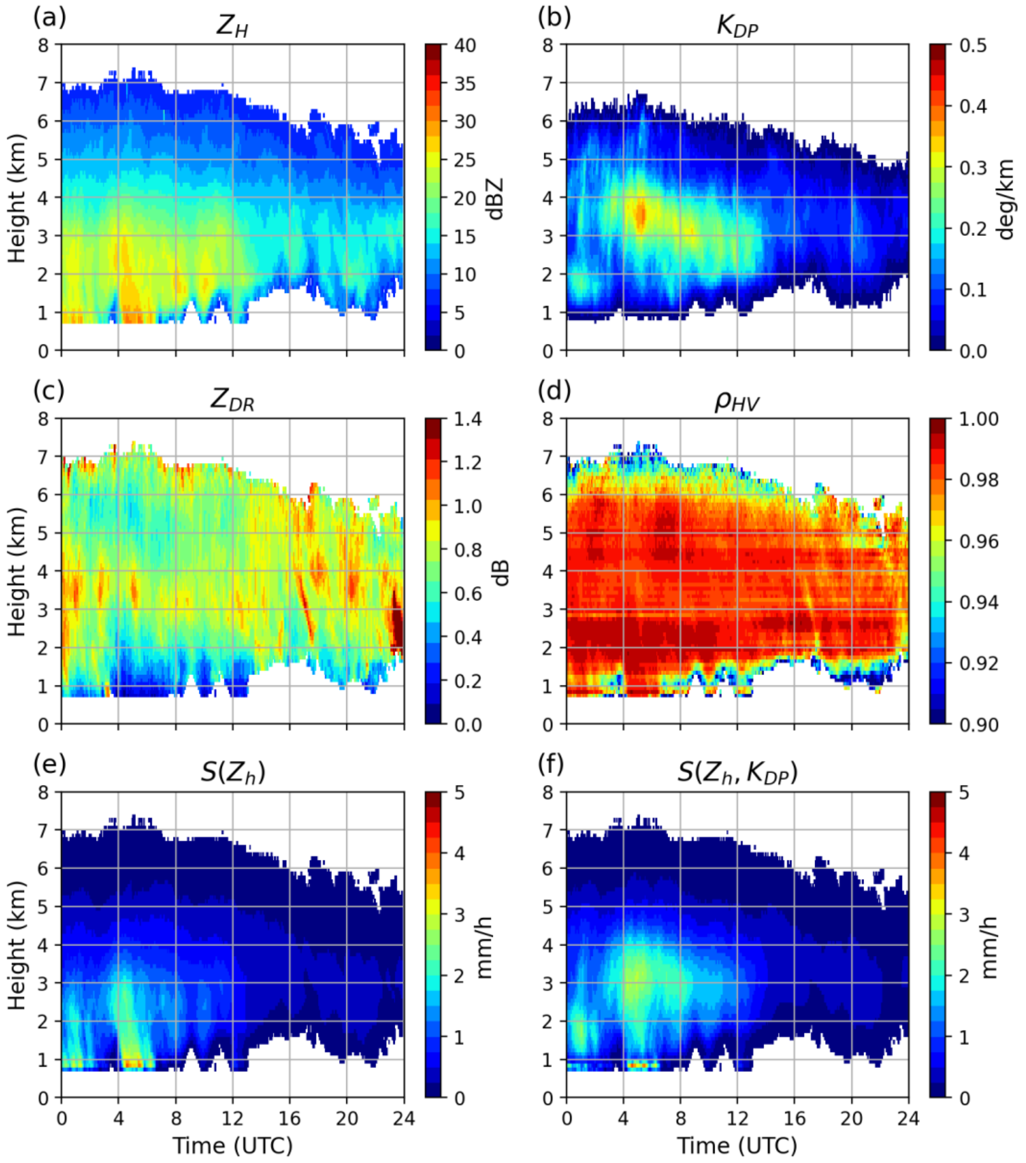
Improve retrievals for snowfall intensity



- $S(Z_h)$ at the **precipitation scan** consistently has **lower NRMSE and higher CC** than those at higher elevation angles across the entire height range.
- For $S(Z_h, K_{DP})$
  - ✓ LV1: different elevation angels perform similarly to each other, but slightly **worse than $S(Z_h)$** in terms of NRMSE.
  - ✓ LV2: both the **1.5- and 2.5-deg** angles display a significant **jump/drop in NRMSE/CC**, giving the worst scores.
  - ✓ LV3-4: the 1.5-deg angle yields the **lowest NRMSE**.
  - ✓ LV5: the **precipitation scan outperforms** those at the higher elevation angles.

WP-P1-3: Polarimetric QPE in snow and mixed-phase regions

Improve retrievals for snowfall intensity



- The change in the $S(Z_h, K_{DP})$ performance at different height levels (elevation scans) can be attributable to **deficiencies in K_{DP}**.

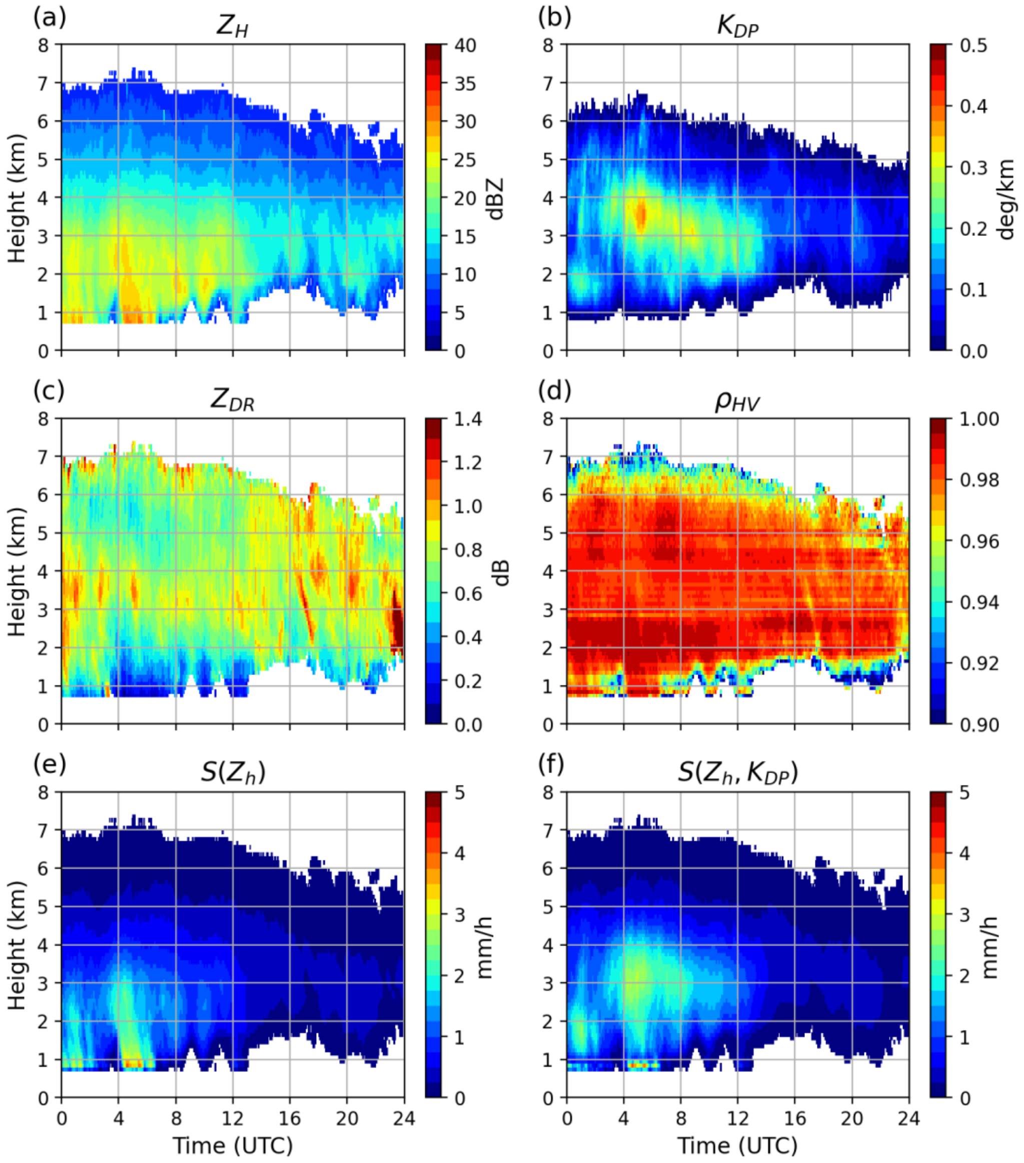
  → The K_{DP} retrieval process amplifies the extent of K_{DP} values decreasing towards the ground, leading to near-zero values at low altitudes.

- The enhanced snowfall rates in the DGL is only mirrored by $S(Z_h, K_{DP})$. In contrast, $S(Z_h)$ exhibits an increase below the dendritic growth layer (DGL), eventually reaching the surface with some delay.

  → the **height-dependent combination** of $S(Z_h, K_{DP})$ and $S(Z_h)$ is recommended.

WP-P1-3: Polarimetric QPE in snow and mixed-phase regions

Improve retrievals for snowfall intensity



A single relationship $S(Z_h, K_{DP})$ cannot capture the high diversity of snowflakes and ice crystals

→ Define classes and accordingly apply different S relationships

■ Signatures to consider for the classes

✓ DGL detected with ZDR and KDP

✓ Downward gradients below the DGL

✓ High ZDR at cloud top, indicating pristine ice with high habit diversity

✓ Secondary ice production manifested in KDP enhancements