Hydrometeor partitioning ratios for dual-frequency space-borne and polarimetric ground-based radar observations

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Objectives/Motivation

Objectives

- **Derivation** and **verification** of hydrometeor partitioning ratios (**HPR**) estimated with hydrometeor classifications (**HMC**) based on dual-frequency (**DF**) or dual polarization (**DP**) measurements by combining ground-based (**GR**, NEXRAD) and space borne radar (**SR**, GPMs Dual-Frequency Precipitation Radar DPR) observations.

Motivation

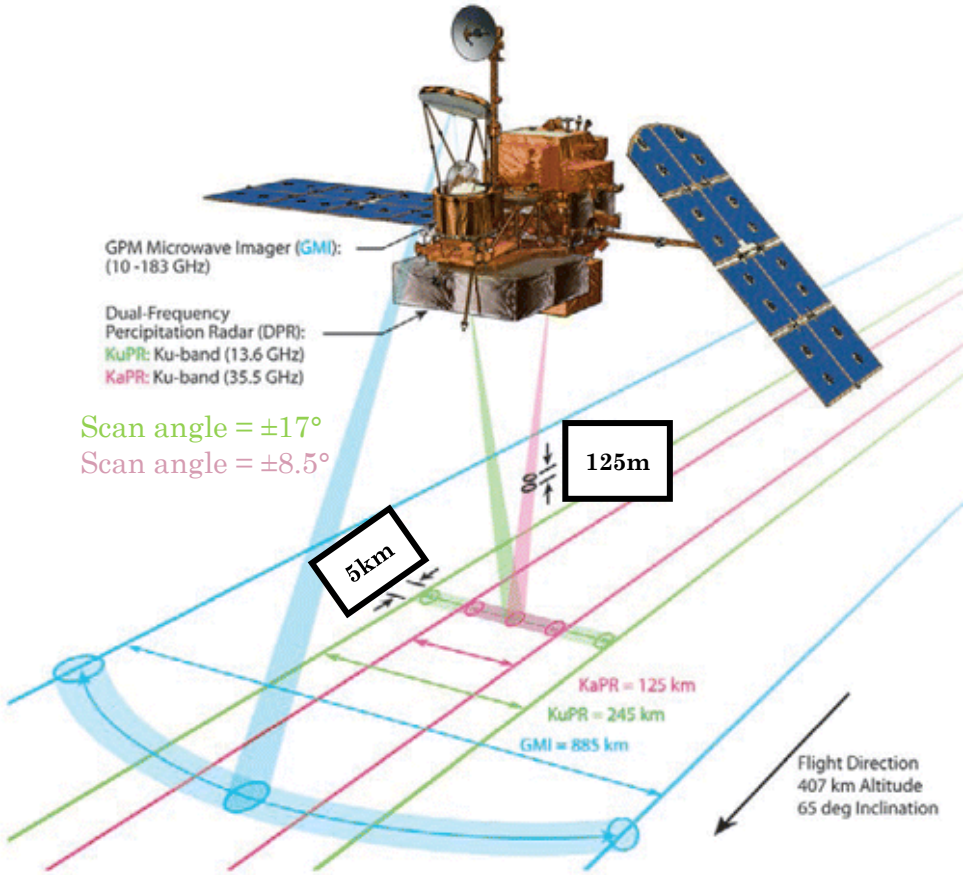
- Typically, DP-based HMC provide information about the **dominant hydrometeor** class in the resolved radar volume and **do not provide** information about the **coexisting recessive hydrometeor** classes.

- GPMs DPR state of the art hydrometeor classification (3D) is reduced to a separation into **liquid**, **mixed** and **solid** via **melting layer** detection.

- SR-based HPR estimates can be an excellent tool for **evaluating NWP** models in **extreme weather** regions such as Hurricane Alley, especially due to the **absence** of **GR measurements** in such areas.

Data

Global Precipitation Mission Core Satellite (GPM)

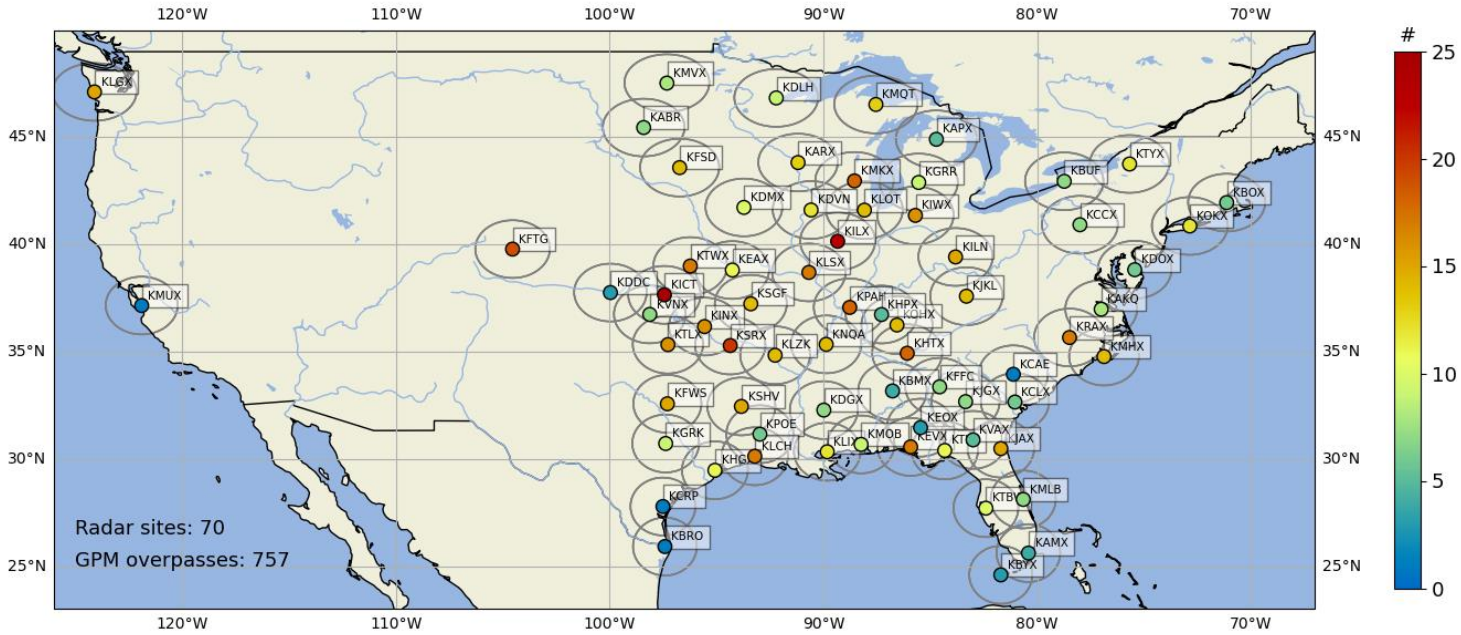


Furukawa et al. 2013

Ku-band : 13.6 GHz

Ka-band : 35.5 GHz

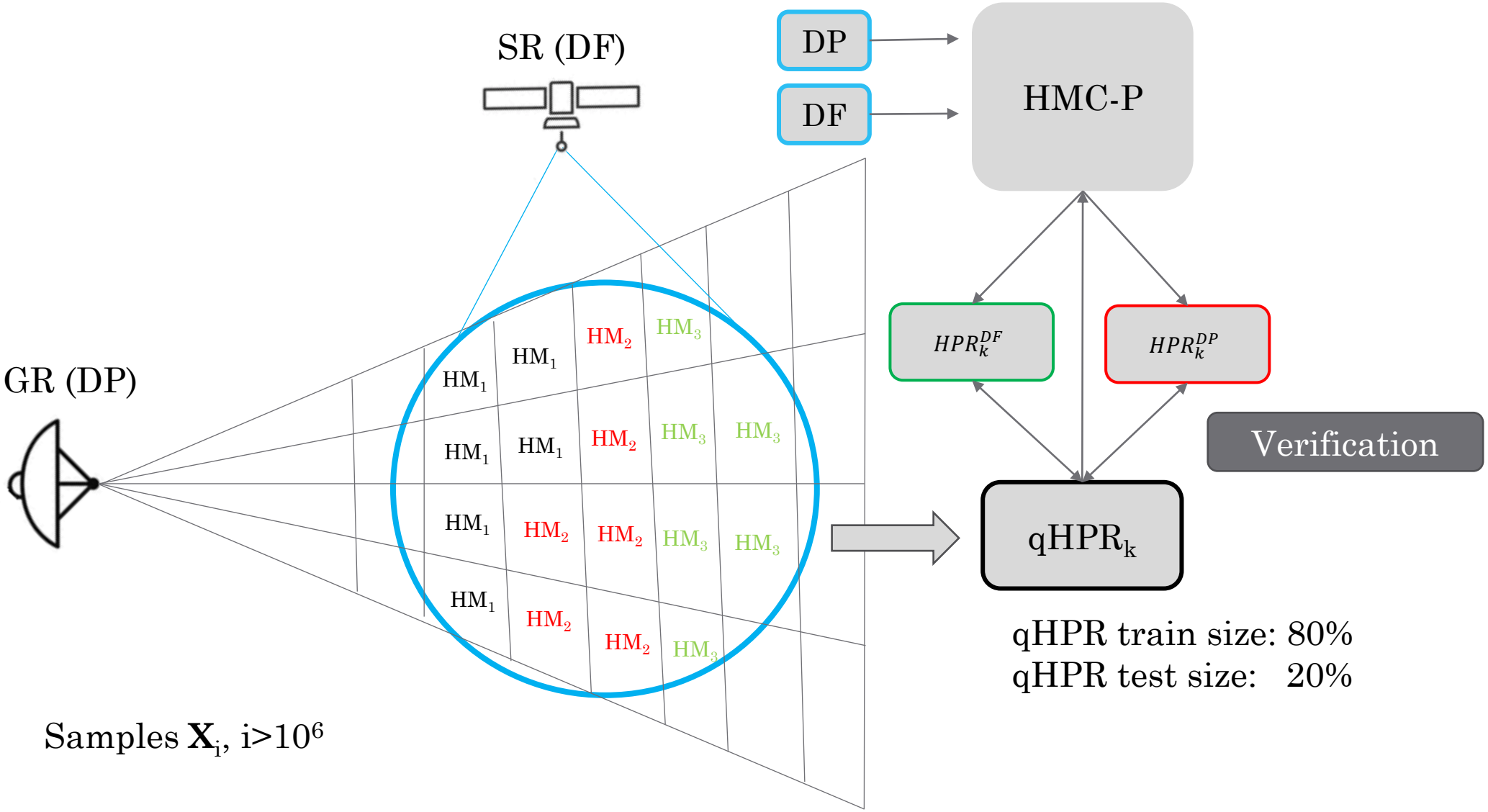
NEXRAD



The Global Precipitation Measurement Mission (GPM) Ground Validation (GV) provides quality-controlled **S-band (~3GHz)** radar data. For this study **757** volume scans between **2014** and **2023** with GPM overpass are used.

Resolution: **Δr**: 250m, **Δφ**: 0.5°/1°, **Δθ**: 0.5°-19°

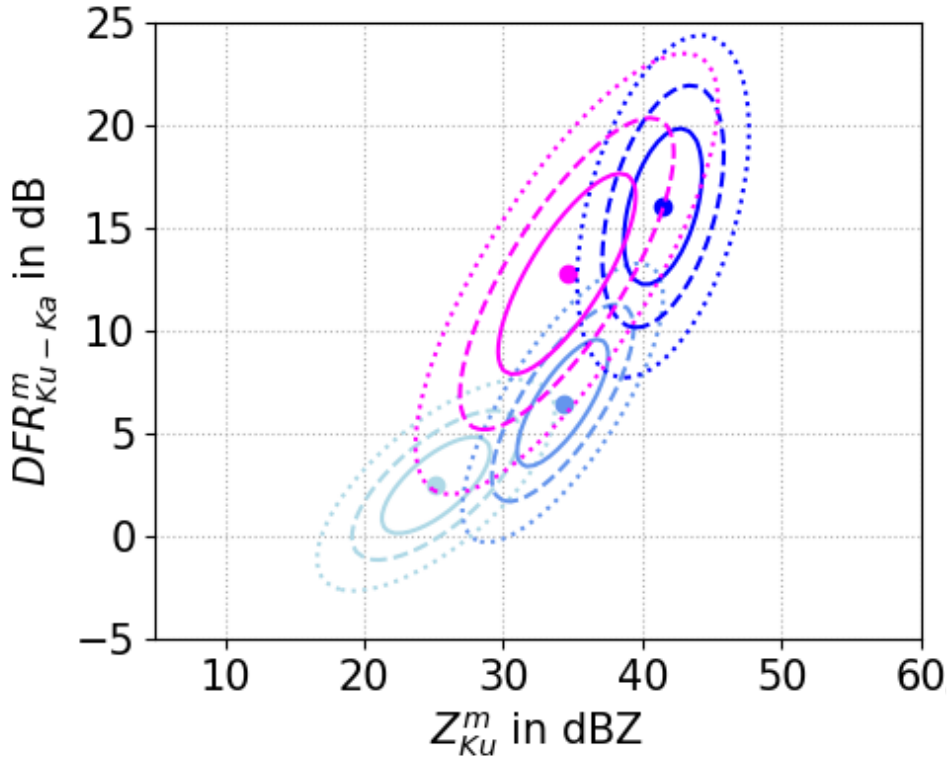
Idea and Strategy



Estimation of Hydrometeor Partitioning Ratios

$$X^{DF} = \begin{bmatrix} Z^m_{K_u} \\ DFR^m_{K_u - K_a} \\ T \\ RT \end{bmatrix}$$

Light Rain
Moderate Rain
Heavy Rain
Big Drops



HPR_{BD}=50%
HPR_{MR}=50%

Multivariat Normaldistribution (MVND):

Refined approach of Besic et al. 2018

$$p_k(\boldsymbol{X}|\boldsymbol{\mu_k}, \boldsymbol{C_k}) = \Lambda \exp\left(-\frac{1}{2}(\boldsymbol{X}-\boldsymbol{\mu_k})^{\mathrm{T}} \boldsymbol{C_k}^{-1} (\boldsymbol{X}-\boldsymbol{\mu_k})\right)$$

$$\Lambda = 1/\sqrt{(2\pi)^d |\boldsymbol{C_k}|}$$

Centroids:

$$\boldsymbol{\mu}_\mathrm{k} = \frac{\sum_{i=1}^{n} w_i \boldsymbol{X_i}}{\sum_{i=1}^{n} w_i}$$

Weights:

$$w = \mathrm{qHPR}_k$$

Covariance Matrix:

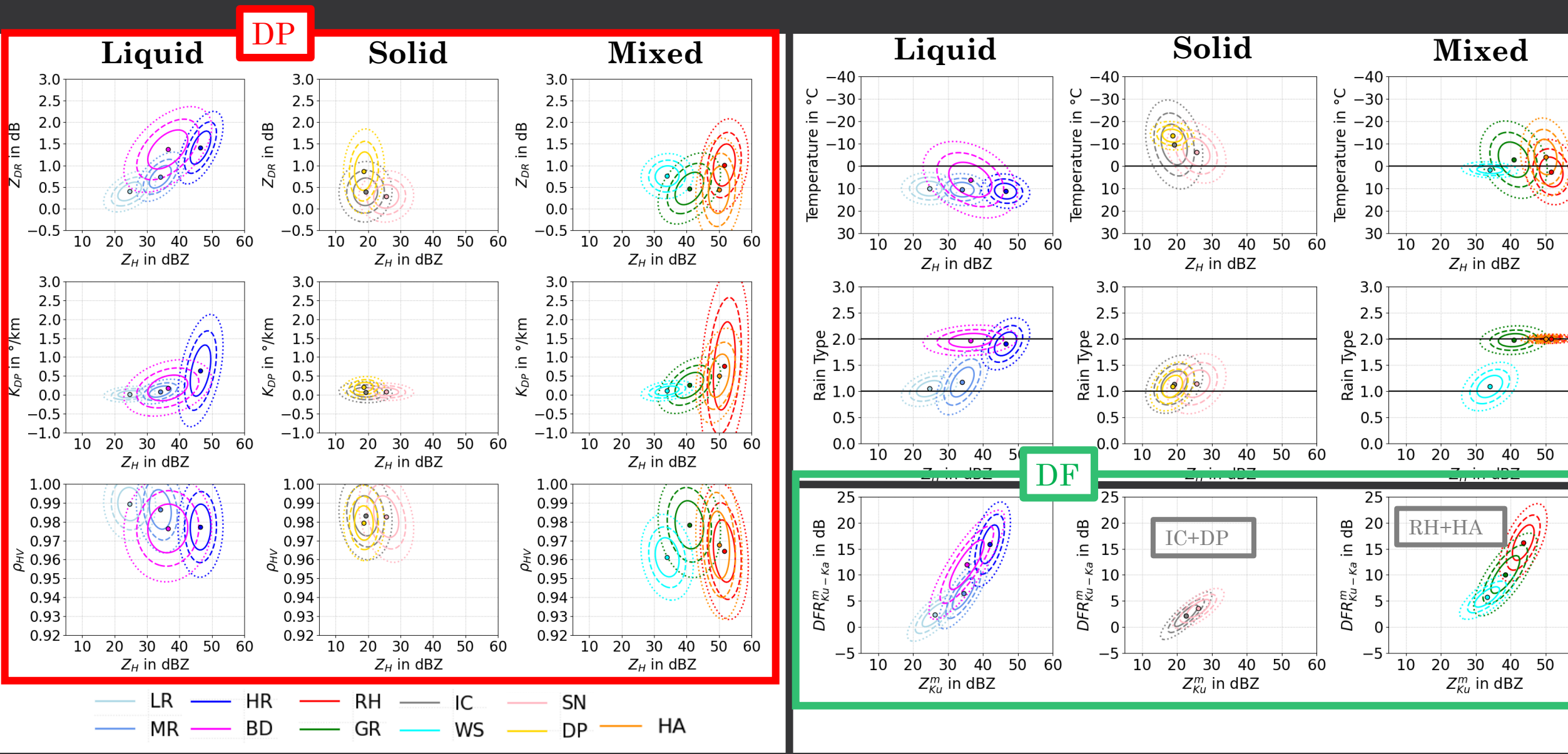
$$\boldsymbol{C}_\mathrm{k} = \frac{\sum_{i=1}^{n} w_i \mathrm{E}\left((\boldsymbol{X_i}-\boldsymbol{\mu_k})(\mathbf{X_i}-\boldsymbol{\mu_k})^{\top}\right)}{\sum_{i=1}^{n} w_i}$$

Samples $\mathbf{X}_i$, i>10^6

Hydrometeor Partitioning Ratio (HPR):

$$\mathrm{HPR}_k = 100 \cdot \frac{W_k(T)\, p_k(\boldsymbol{X})}{\sum_{k=1}^{n} W_k(T)\, p_k(\boldsymbol{X})}$$

MVND for DP and DF



Verification of $HPR^{DP/DF}$

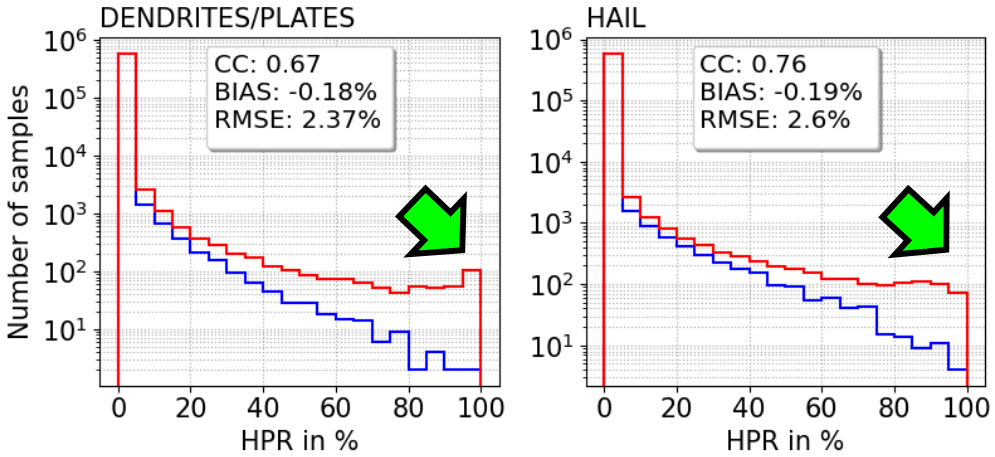
Test size: 20%

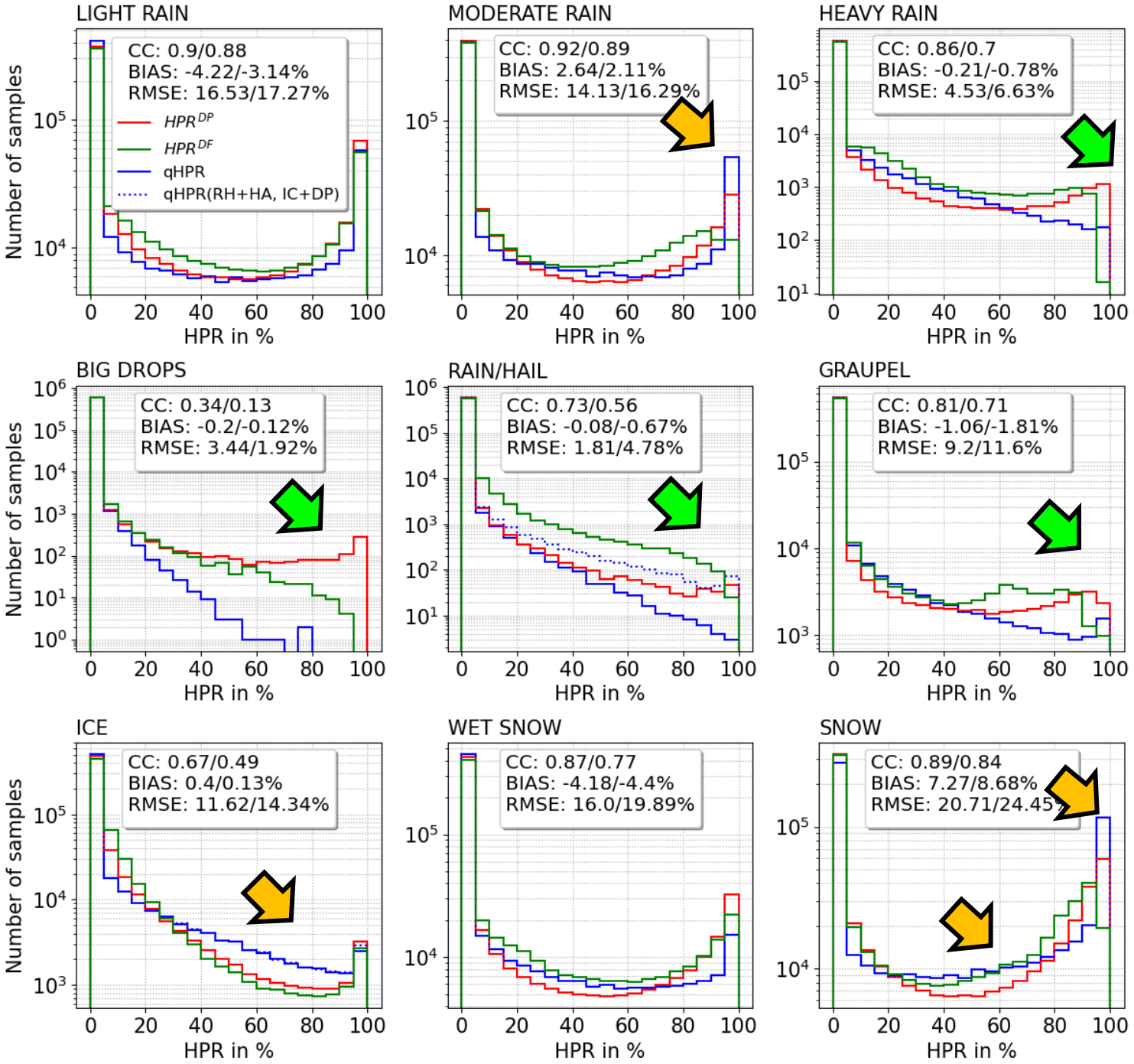
HPR^{DP}
HPR^{DF}
qHPR
qHPR(RH+HA, IC+DP)

Overestimation

Underestimation

➢ **Performance:** $HPR^{DP} > HPR^{DF}$





A Case Study - GPM Overpasses NEXRAD

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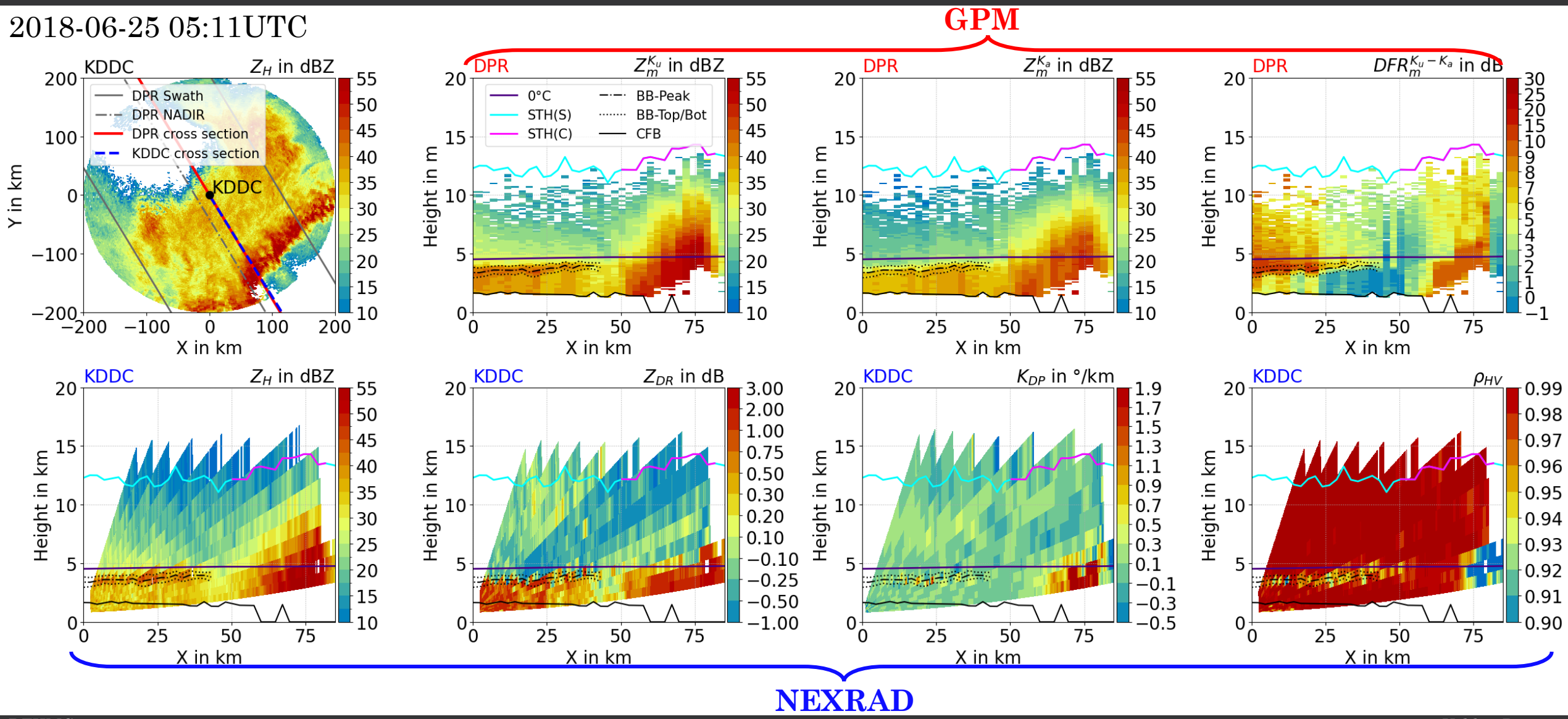
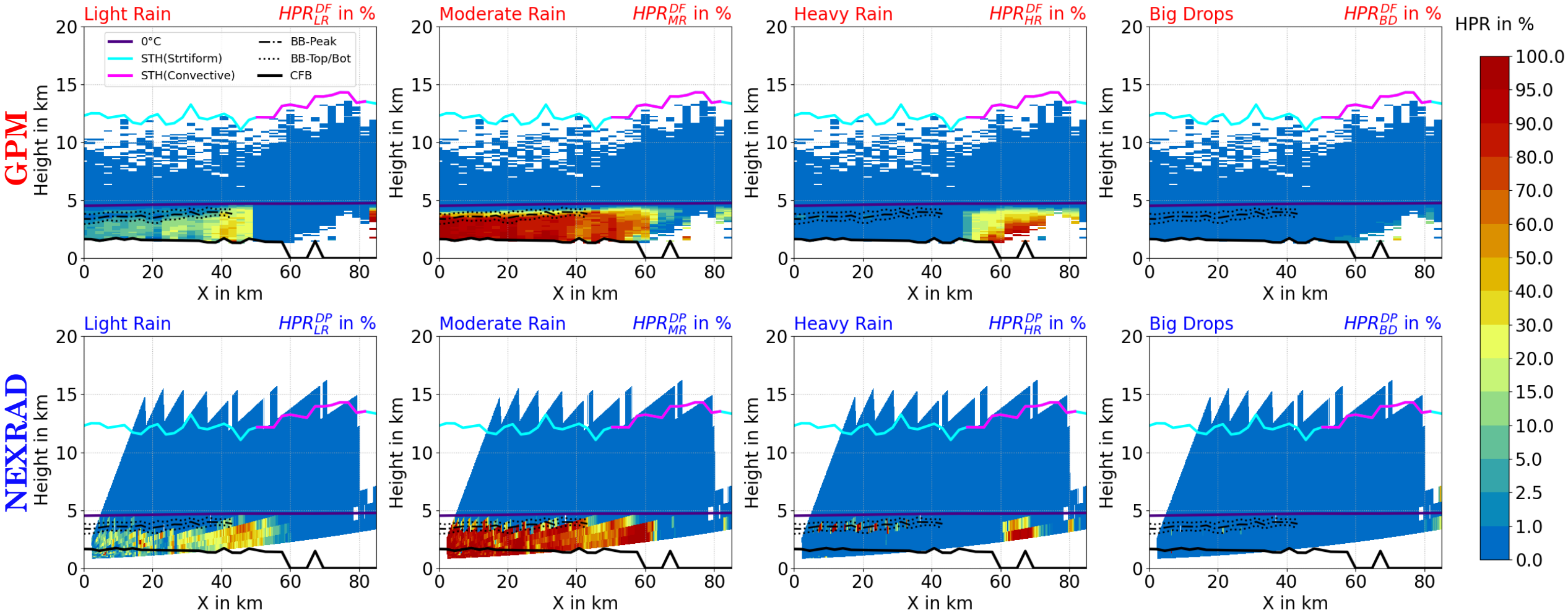
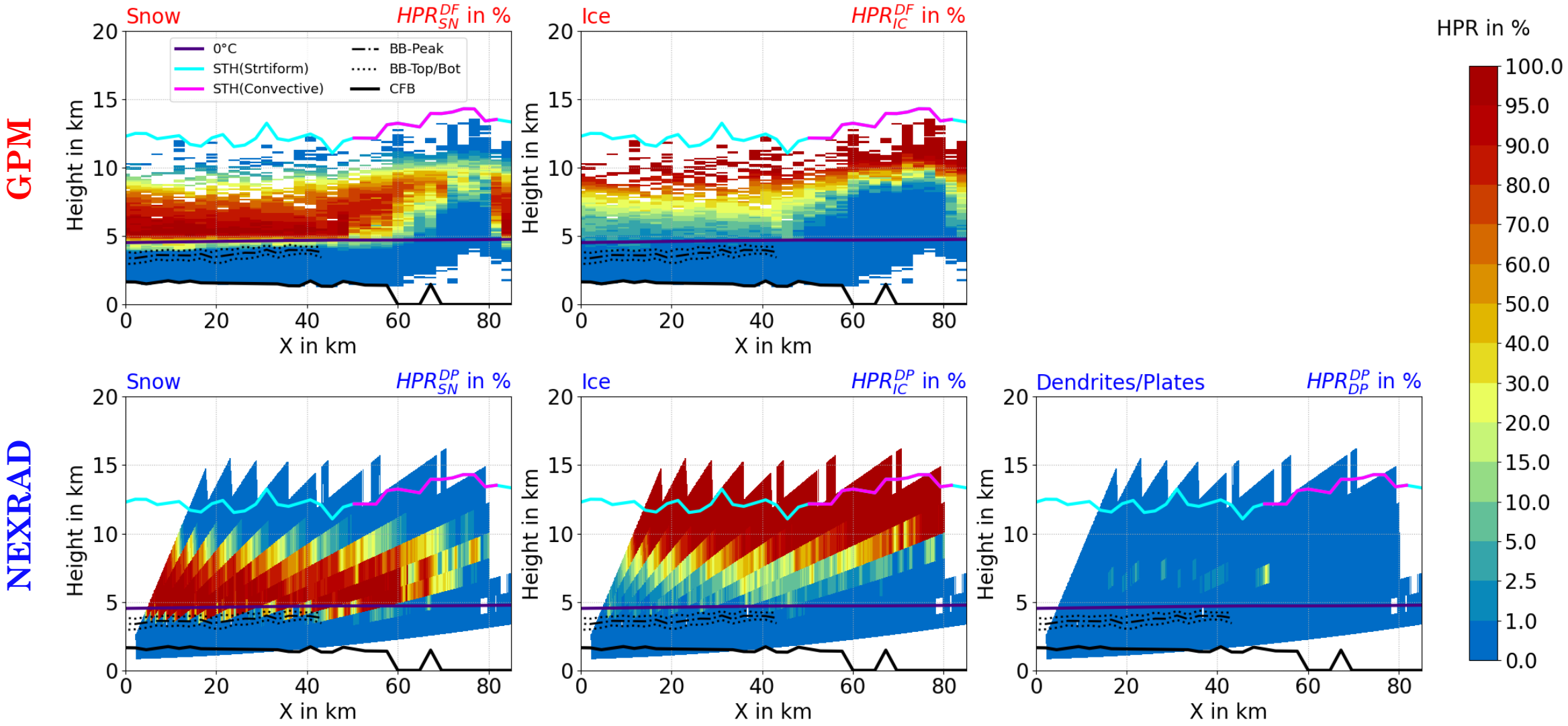


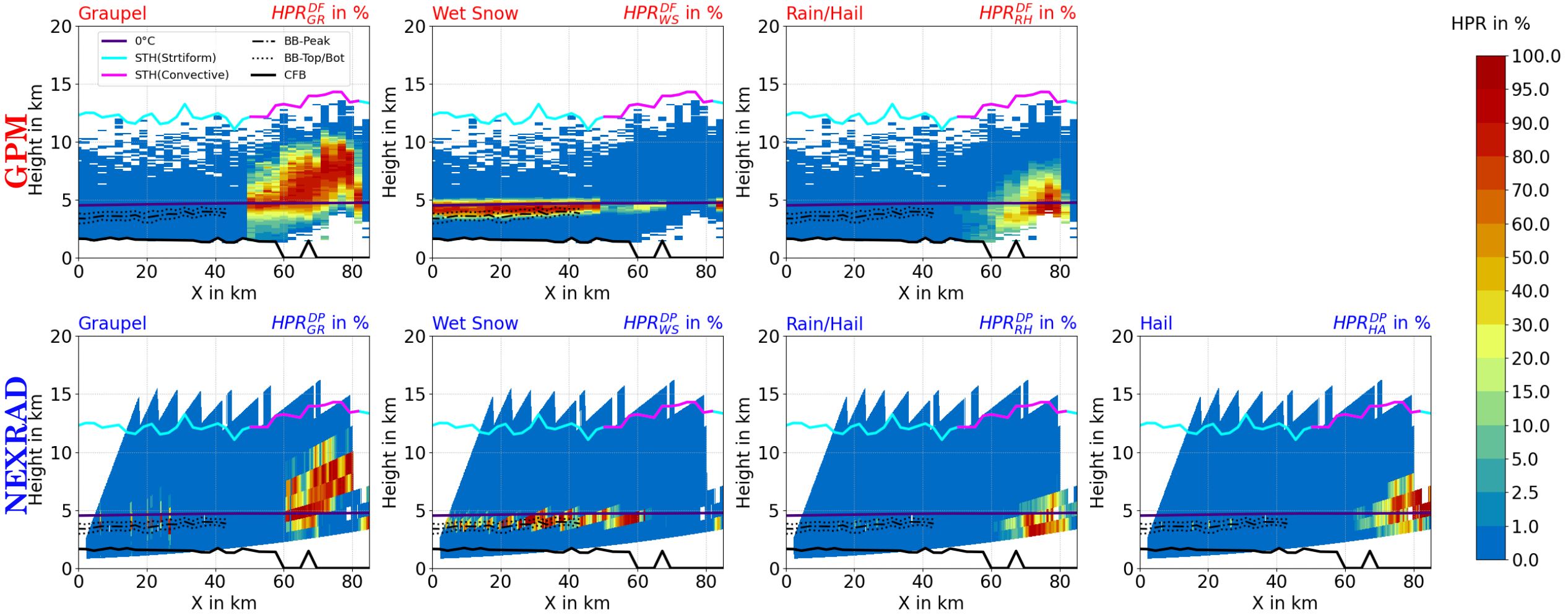
$HPR^{DF/DP}$-Estimates for **liquid** hydrometeors



HPR$^{DF/DP}$-Estimates for **solid** hydrometeors



$HPR^{DF/DP}$-Estimates for **mixed** hydrometeors



Summary

- It is possible to derive **HPR** based on DF/DP only observations by combining DPR and NEXRAD observations.
- **HMC-P reproduces** the **qHPR** ("ground truth“) to a **high degree**.
- HPR **Overestimation** of Hail, Graupel, Big Drops, Heavy Rain and Dendrites/Plates.
- HPR **Underestimation** of Moderate Rain, Ice and Snow.
- **Performance:** $HPR^{DP} > HPR^{DF}$
- Direct comparisons of HPR^{DF} and HPR^{DP} show **consistent results**.
- HMC-P is of course not immune to observation artifacts (NUBF).

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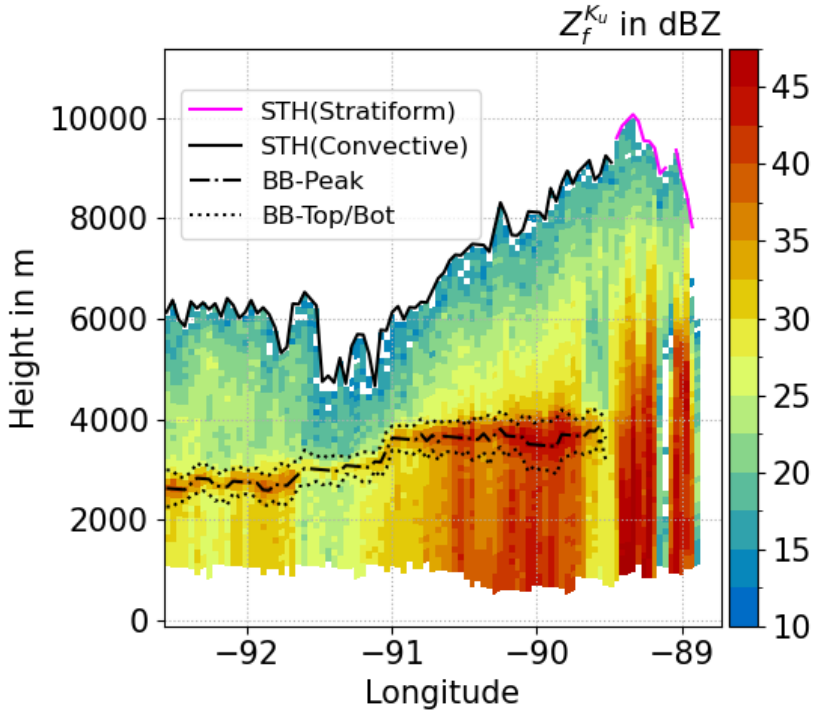
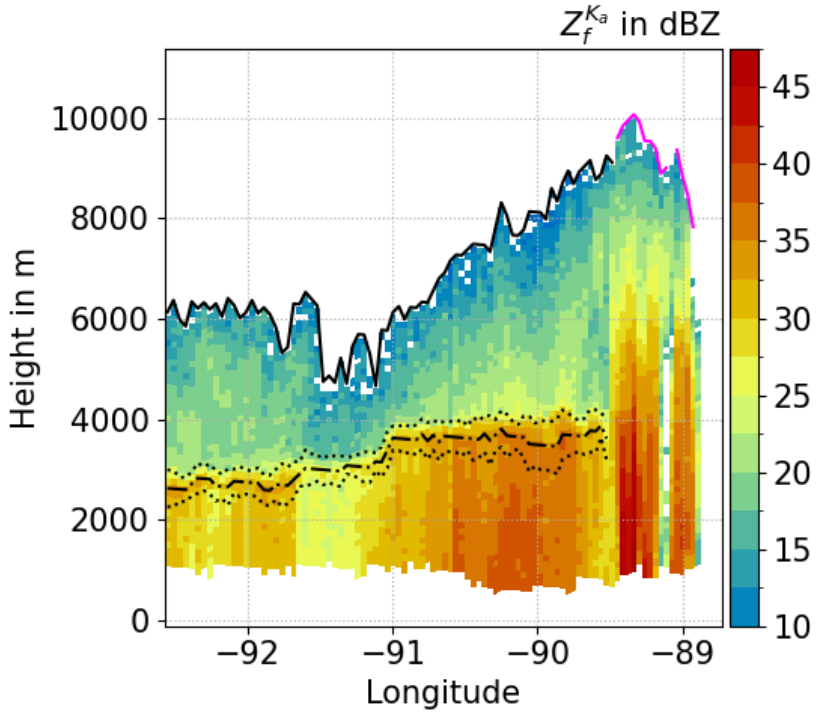
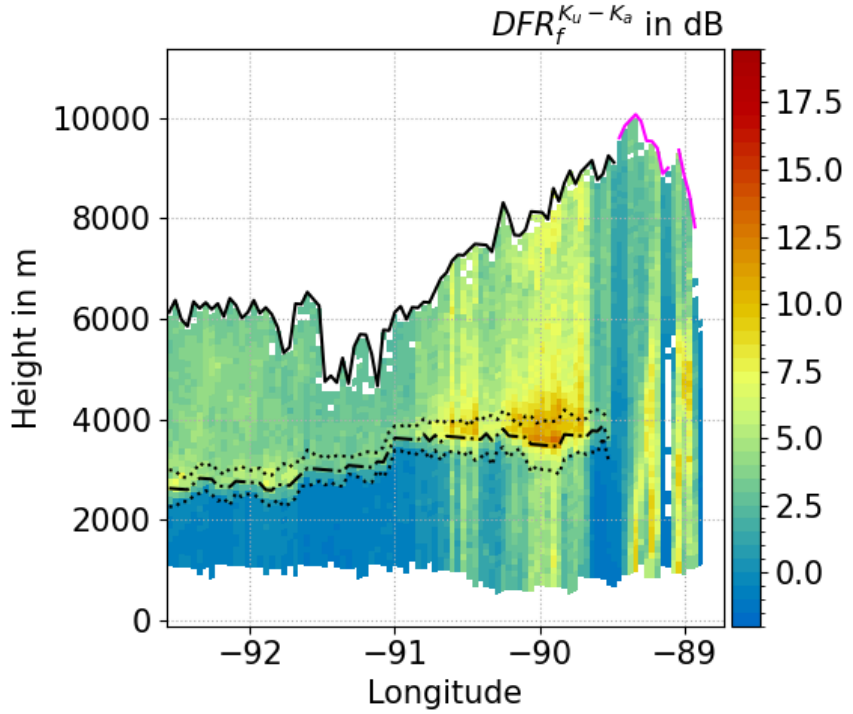
APPENDIX

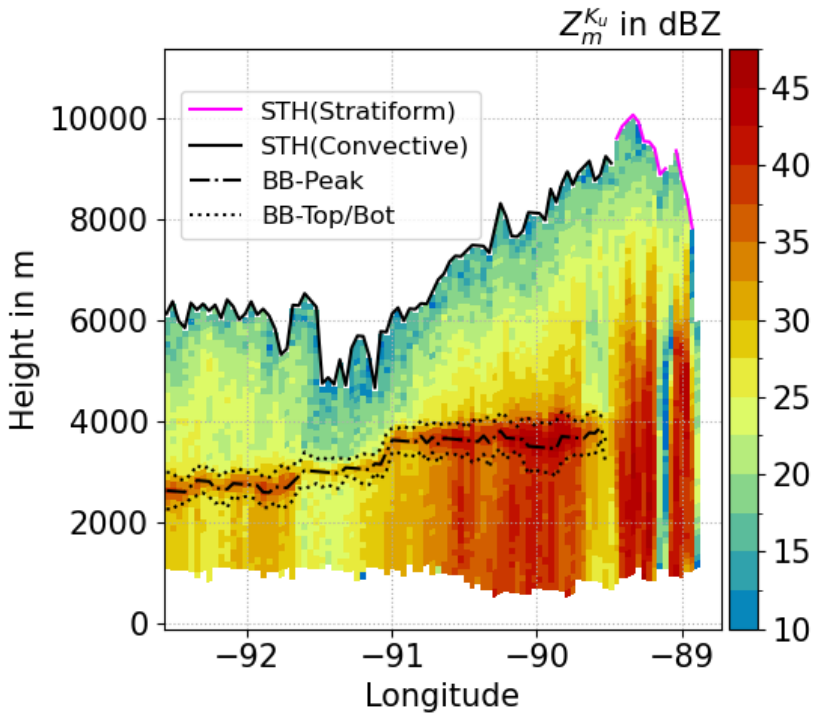
Z_{ku} - Corrected

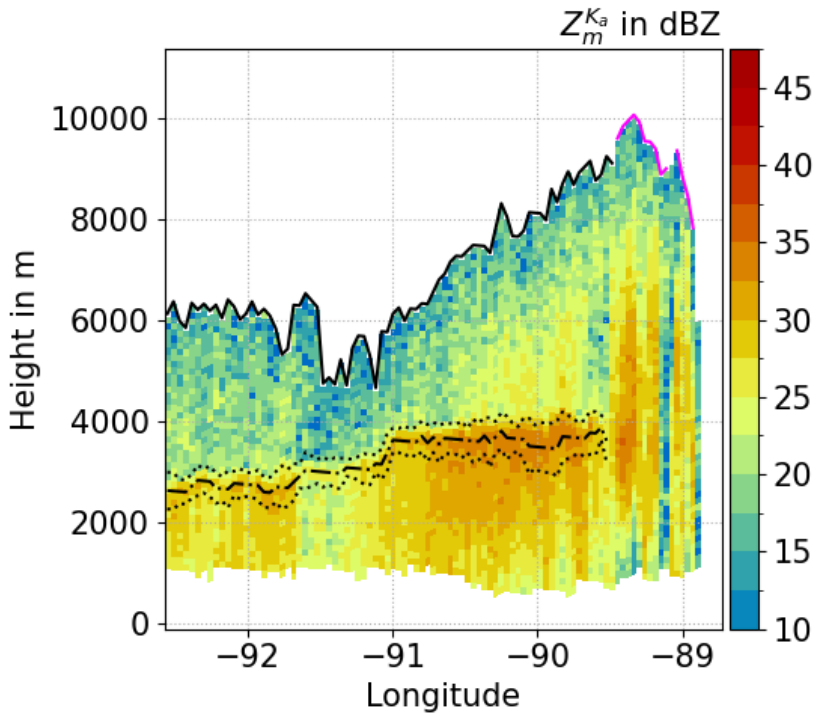


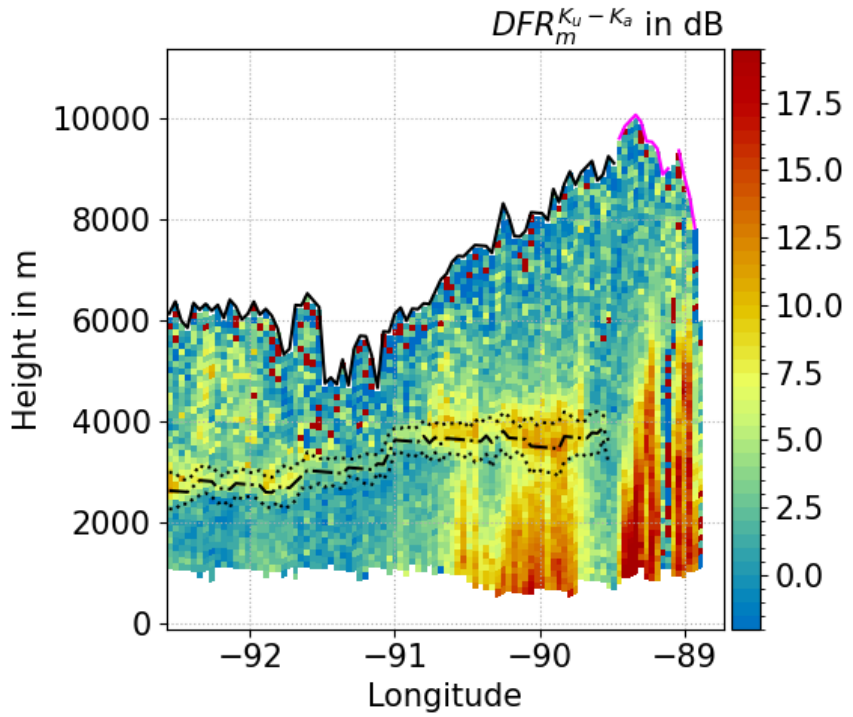




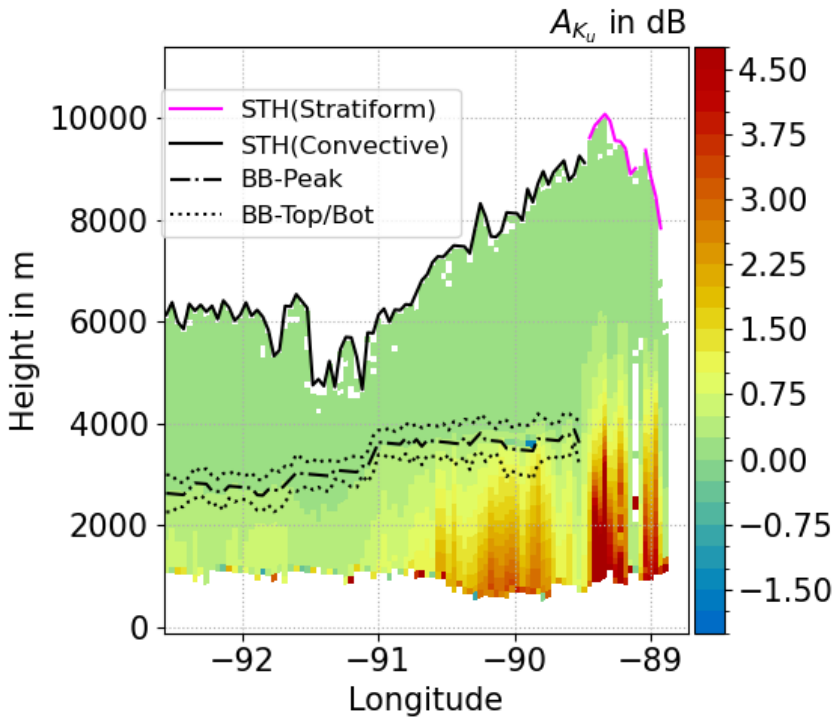
Z_{ku} - Meassured

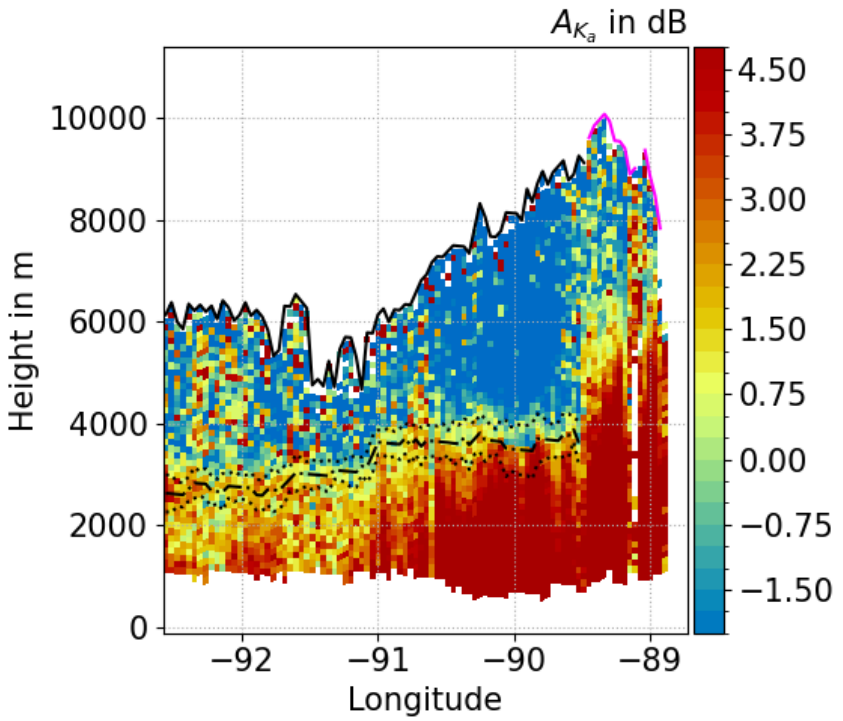


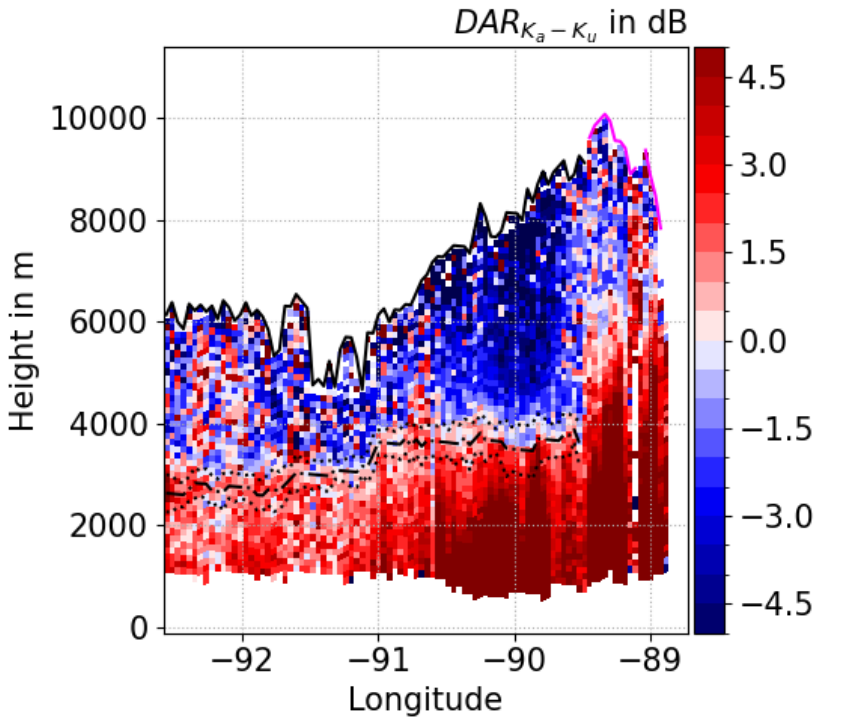




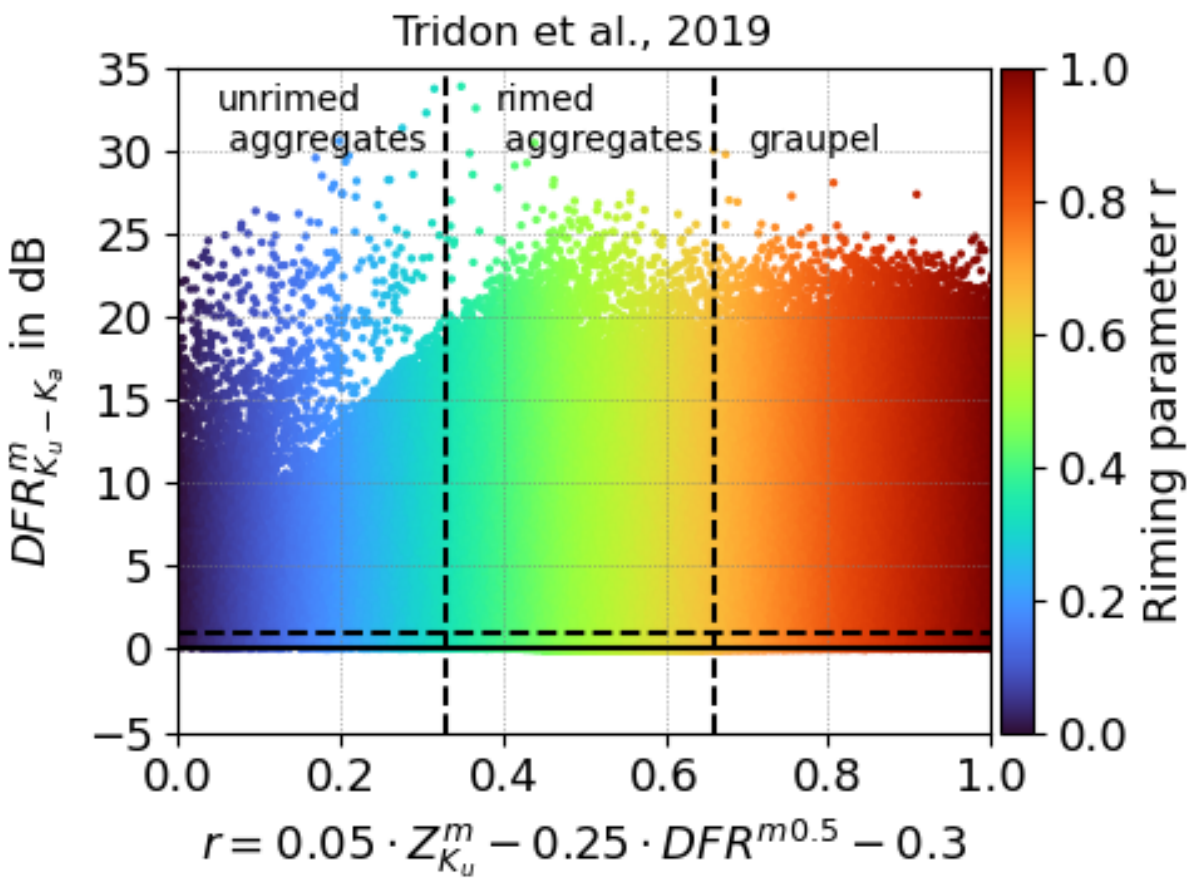
DPR – Attenuation Correction

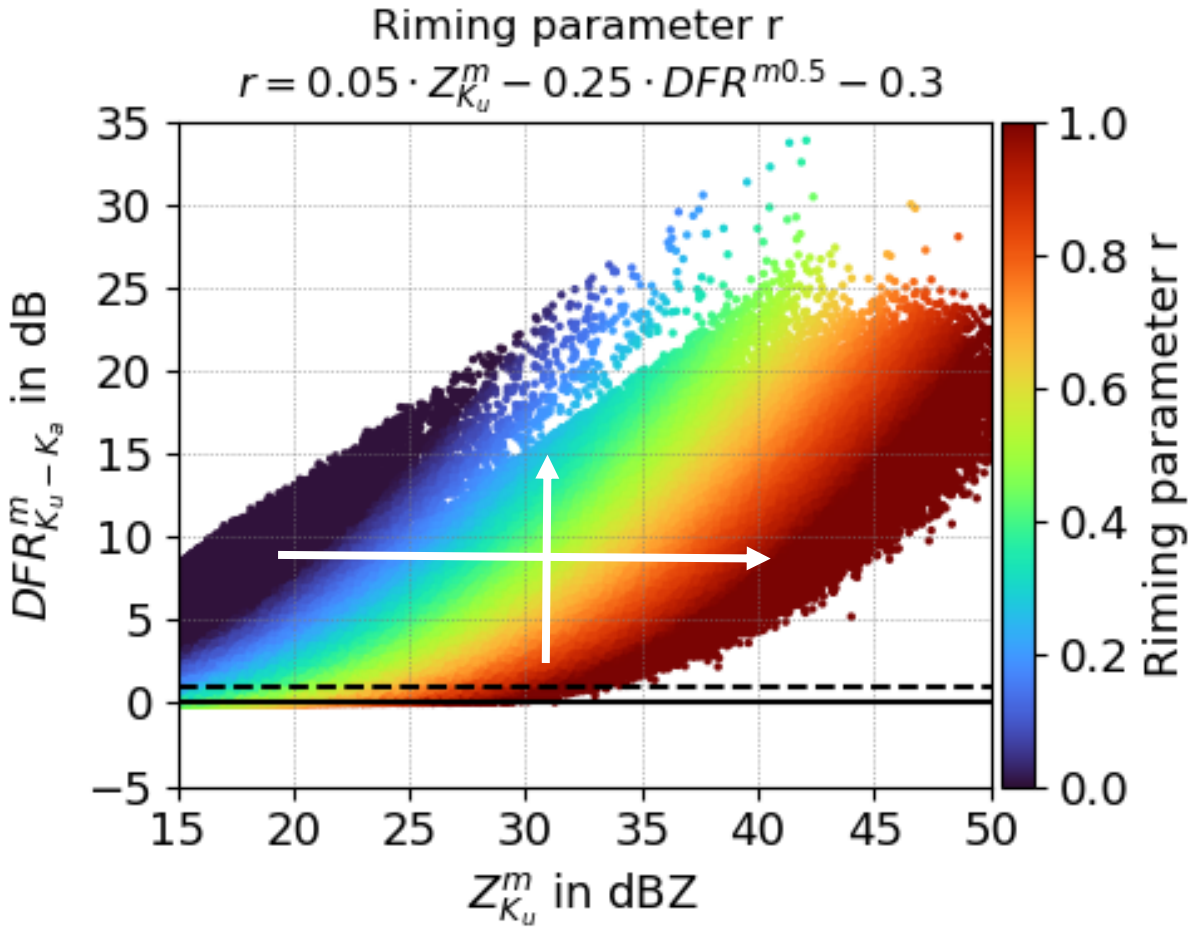




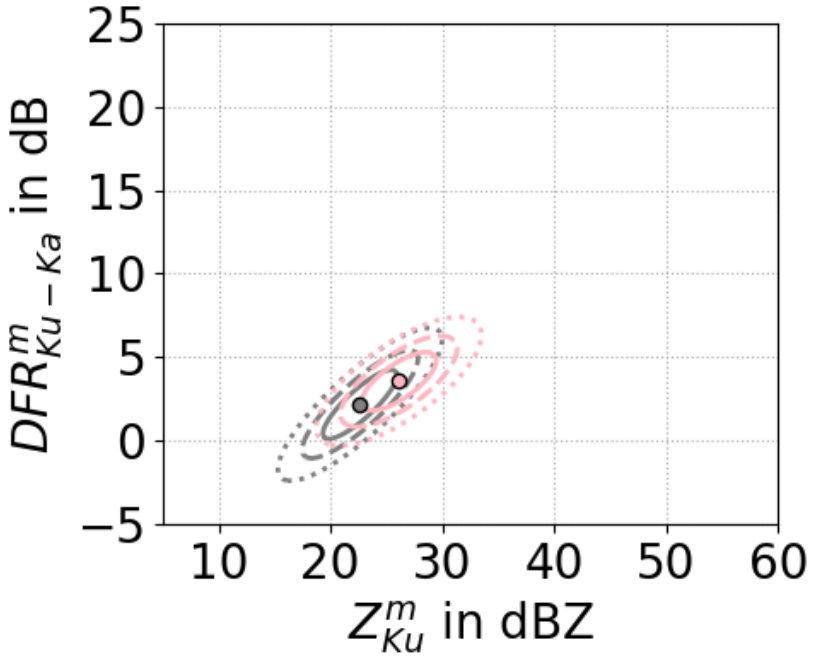


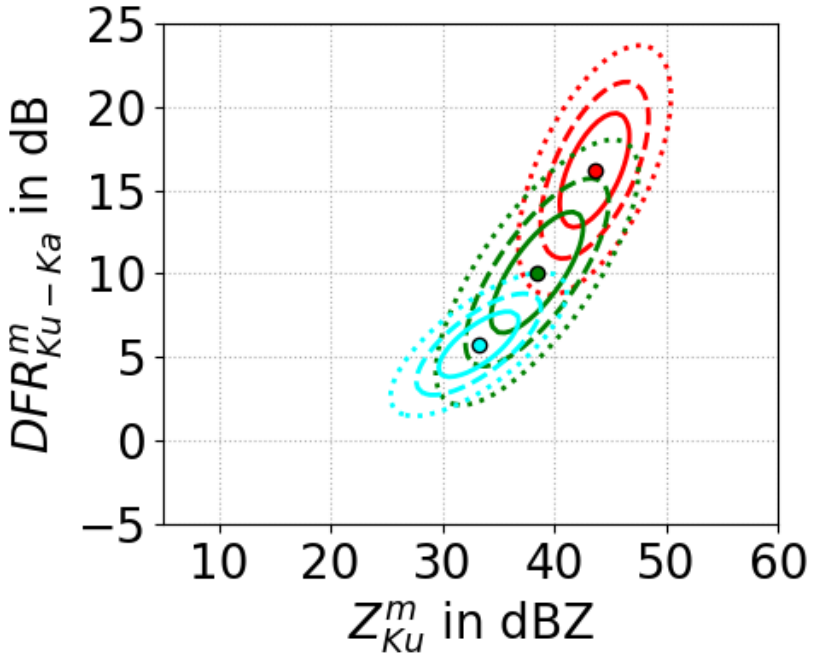
Riming parameter r (Tridon et al. 2019)

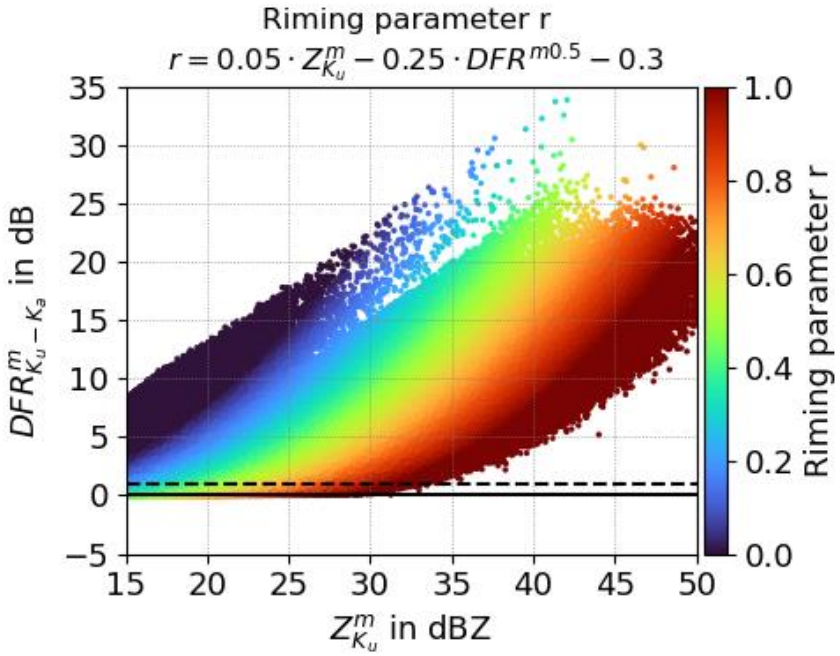




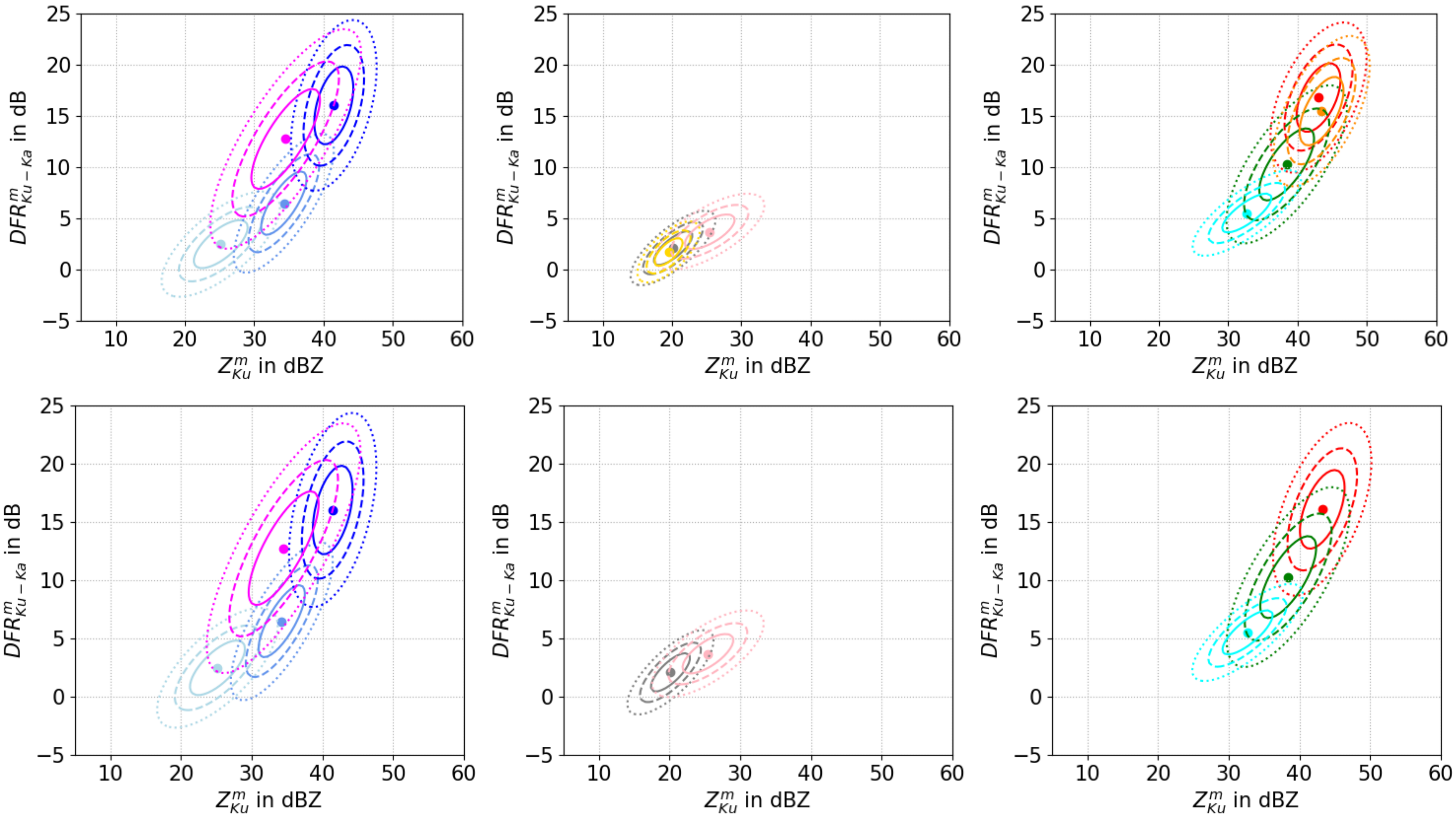
Riming parameter in Z-DFR Space







DP-MVND



Strong overlapping DF-MVND for RH and HA and IC and DP!

RH + HA
IC + DP!