Polarimetric Radar Verification of GPM Satellite-Based Retrievals of the Raindrop Size Distribution

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Outline

- **Motivation and Requirements**
- **Approach, Methods, Data**
- **Verification of basic mission requirement and GPM DSD "drill down"**
- **Summary**

Acknowledgements: T. Berendes (UAH/MSFC), D. Marks (SSAI/WFF), J. Pippitt (SSAI/GSFC), M. Wingo (UAH/MSFC)

Research Support: NASA PMM/GPM (Dr.'s R. Kakar / G. Skofronick-Jackson)

GPM "Core" Satellite Science Requirements

(Termed "Level -1" or "L1")

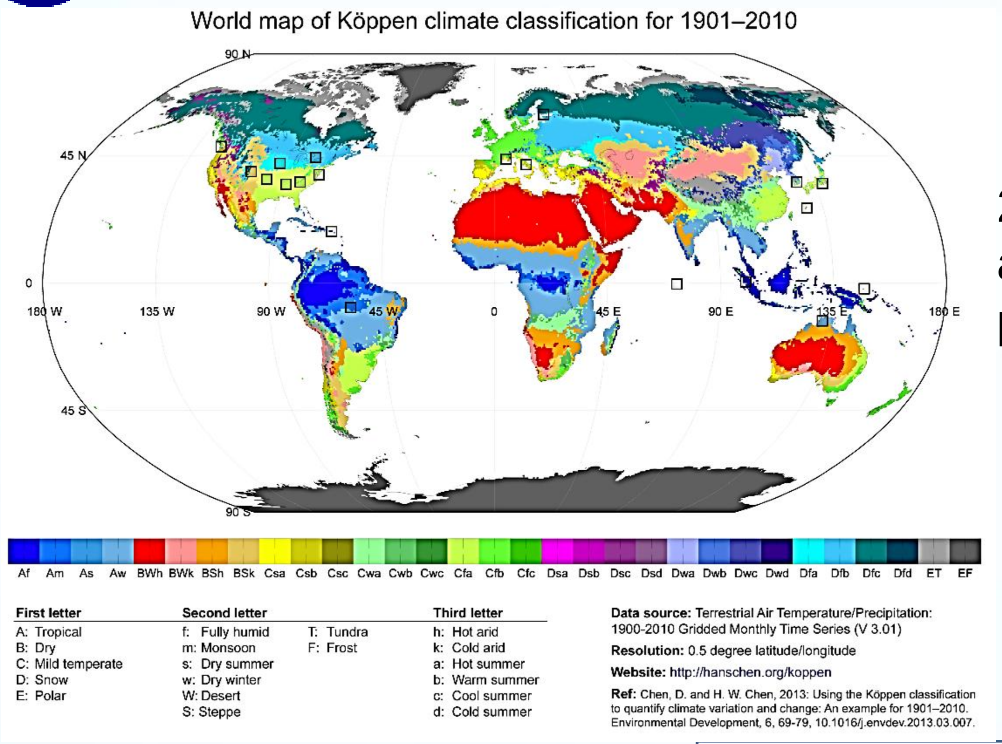
- DPR: *quantify rain rates* between 0.22 and 110 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 5 km*.

- GMI: *quantify rain rates* between 0.22 and 60 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 15 km*.

- **Core observatory radar estimation of the Drop Size Distribution (DSD)- specifically, *D_m to within +/- 0.5 mm*. [note- no N_w requirement]**

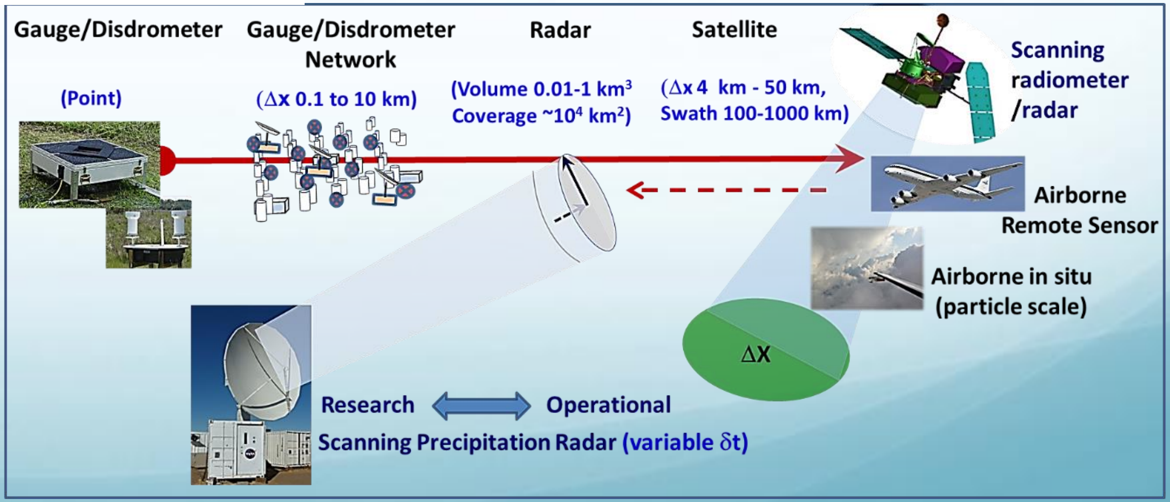
- Core observatory *instantaneous* rain rate estimates at a resolution of 50 km with *bias and random error < 50% at 1 mm hr^{-1} and < 25% at 10 mm hr^{-1}, relative to GV*

Overarching Philosophy

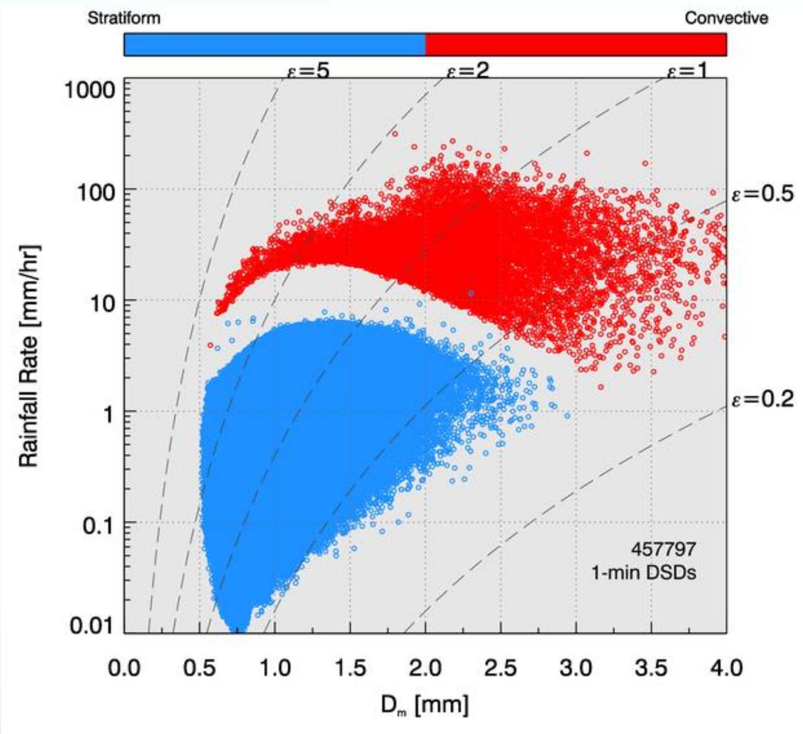


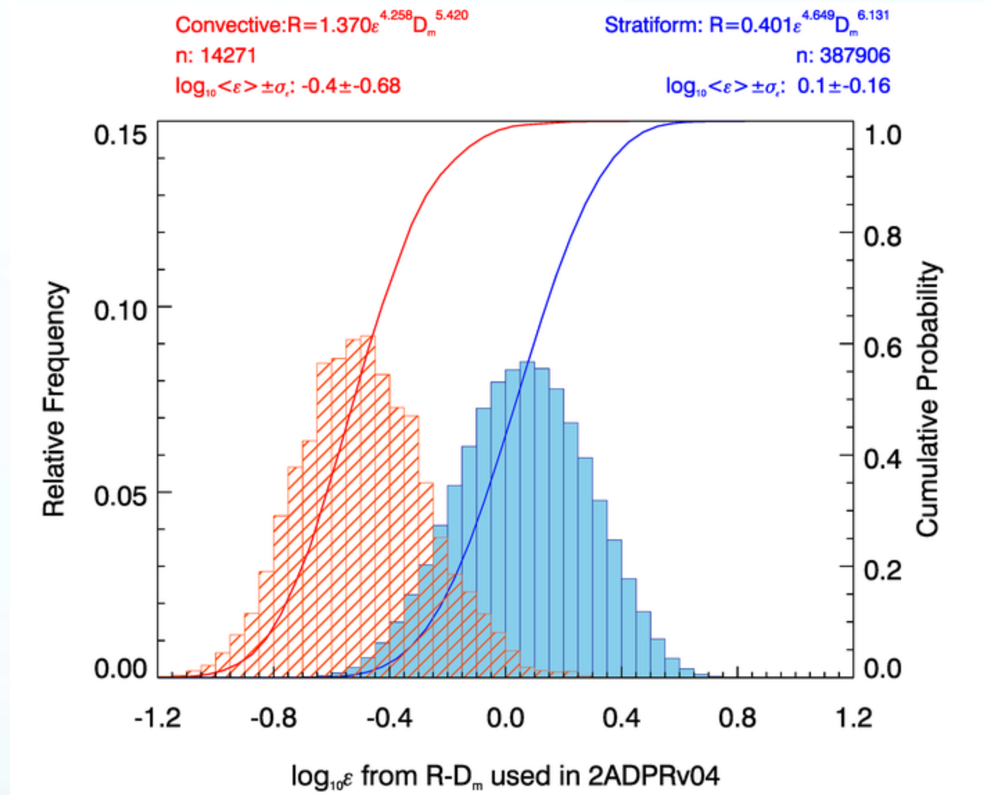
2D Video disdrometer data collected at numerous locations, regimes, and point scales……

…..references dual-pol radar that functions as a "translator" to GPM footprint and swath scales



Ensemble Point Data Useful for Verification of DPR DSD-related Algorithm Assumptions





Algorithm assumes $R = C\,\varepsilon^a D_m^{\,b}$ coefficients a f(rain type) and ε range [5, 0.2];

DPR Algorithm- assumes log normal ε, with <e> ~1;

Disdrometer data suggests ε is smaller for convective vs. stratiform - consistent (with analysis of DPR retrievals);

Need Footprint Comparisons for L1 Requirements

2DVD to Radar: Methodology

2DVD

- 2DVD
  - Field data
- QC/Process
  - ≥100 drops
  - RR>0.1 mm/hr

1-Minute DSD data

Pol Variables

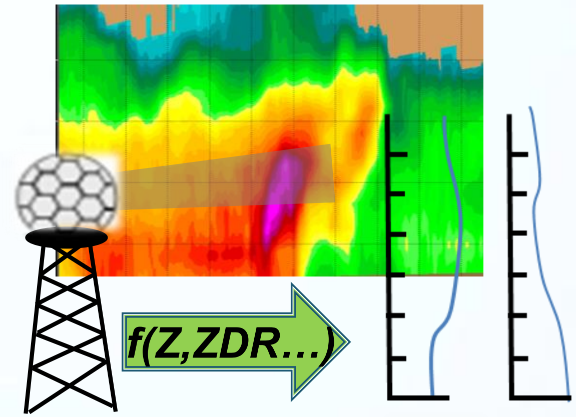
- S-Band
  - Rayleigh-Gans
  - T-Matrix

- ZDR < 4 dB
- D_m 0.5 - 4 mm
- $Log_{10}N_w$ 0.5 - 6

SIFT Poly fit

Point to Volume

Pol Radar



$D_m = aZDR^3+bZDR^2+cZDR+d$

$N_w = aZ*D_m^b$

- Empirical models developed for NASA field campaign "regimes" (Oklahoma, Iowa, Alabama, Mid-Atlantic Coastal, Washington Coast, Appalachians/Piedmont….)
- Aggregated to make "***ALL-regimes***" relationship developed for U.S. continental-scale statistical verification (> 200,000 minutes used)

"ALL" DSD <u>*model-fit*</u> relative errors: *BIAS < 10%, MAE < 15%*

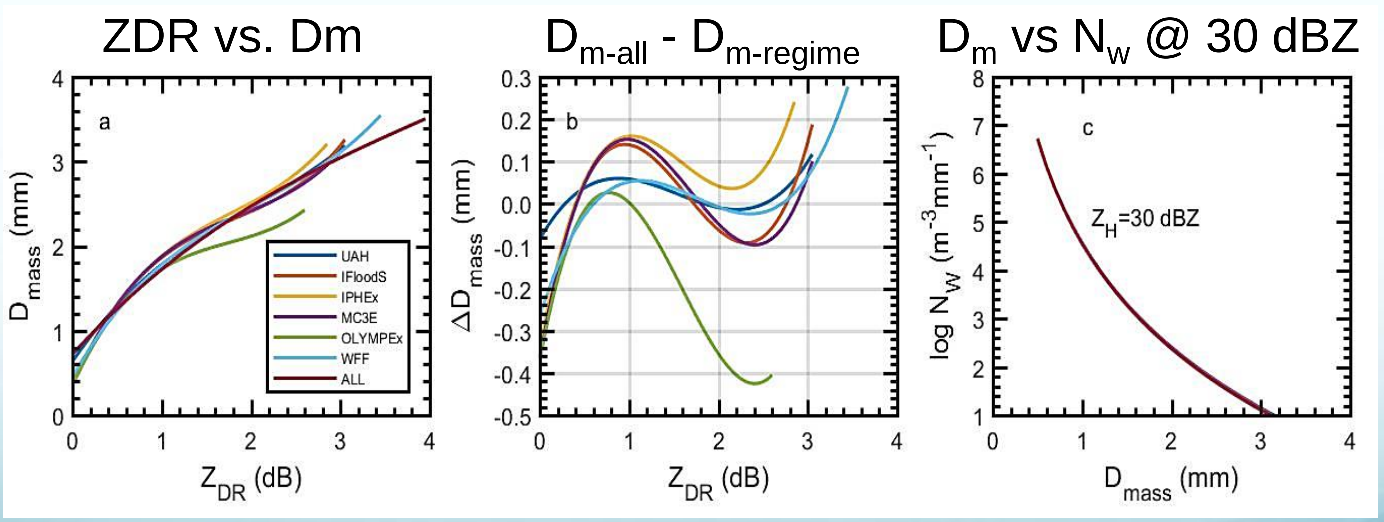
Individual Field Campaign and Aggregate Retrievals

Regime Sub-sample comparisons to NPOL

Field Campaign	Bias	Absolute Bias	Samples
D_m			
IFloods	0.00	0.42	6,610
IPHEx	0.07	0.34	1,058
OLYMPEx	0.03	0.34	1,008
LOG10[N_w]			
IFloods	0.04	0.90	6,610
IPHEx	-0.12	0.89	1,058
OLYMPEx	0.21	0.89	1,008

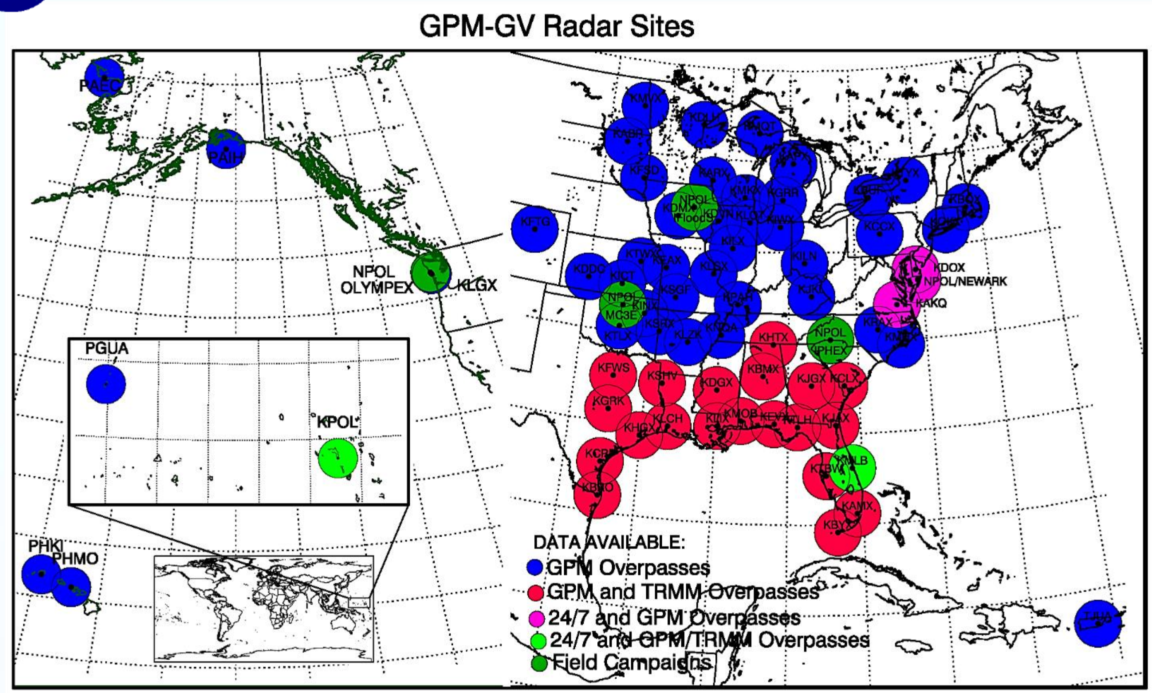
- Sanity check: Examine regime D_m, N_w fits against NPOL observations;
- Examine departure of regime fits from the "ALL" relationship

Tokay et al. 2017 (in preparation)



Application of the "ALL" relationship to certain regimes (e.g., OLYMPEX) and/or the less-frequently sampled large ZDR introduces more uncertainty in D_m; N_w more stable.

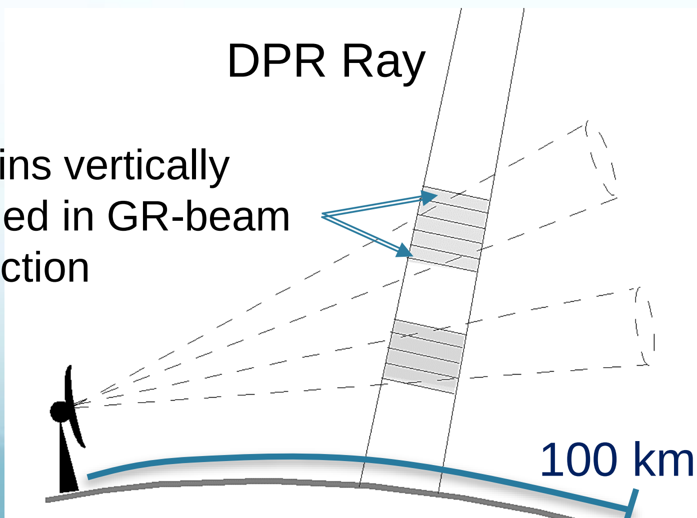
Radar to GPM: Validation Network (VN) Radar Processing



88Ds, NPOL, KWAJ

Network radar datasets used for "statistical" science requirements verification of the DSD

DPR bins vertically averaged in GR-beam intersection



Schwaller and Morris, 2011

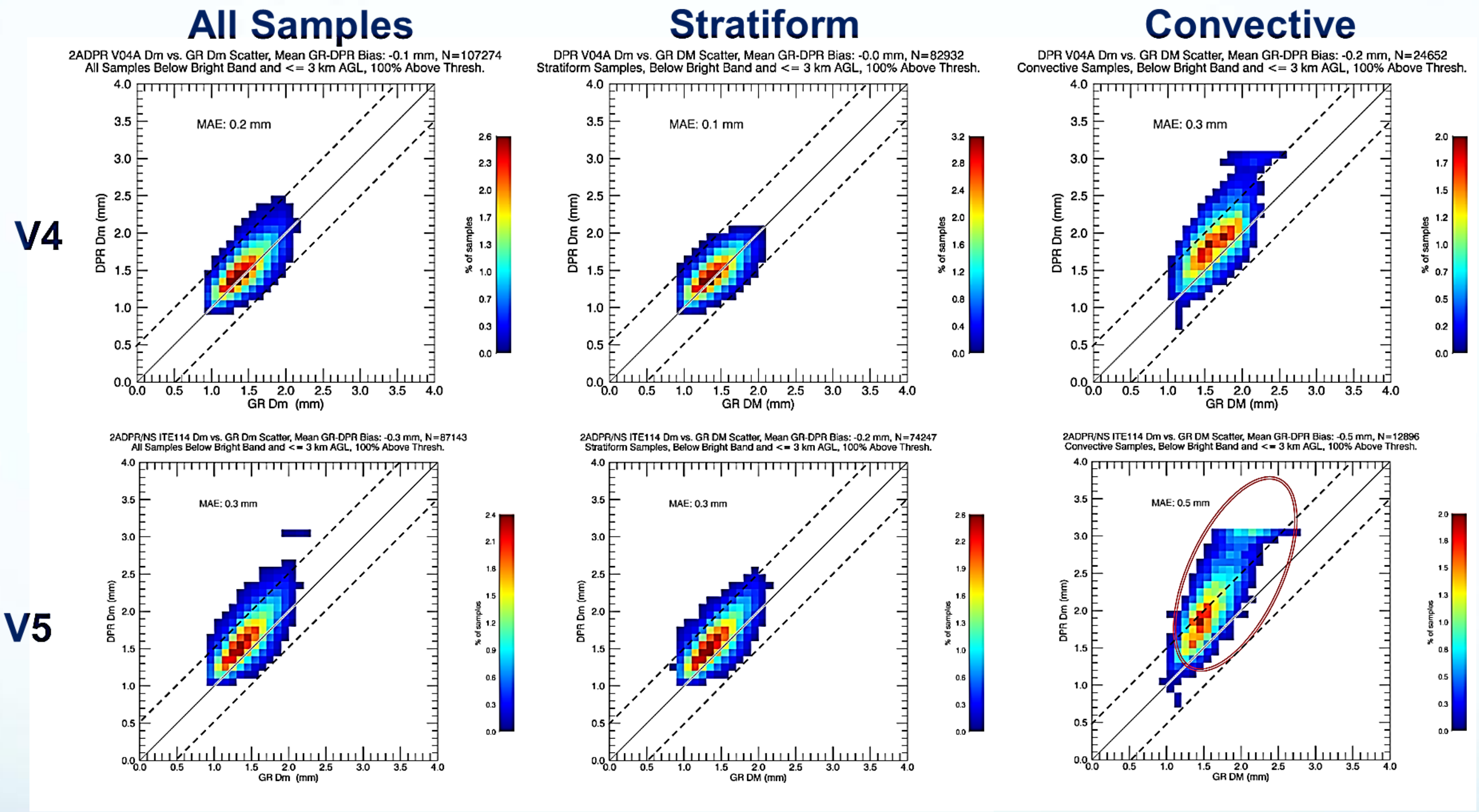
VN Matching

For each GV radar beam, range gates within 100 km of a given radar are geometrically volume-matched to intersecting DPR rays

Products (e.g., select DPR variables, Polarimetric moments, ***DSD***, HID, RR…) are stored in the VN-database.

L1 Requirement: Continental Scale VN-GPM Comparisons

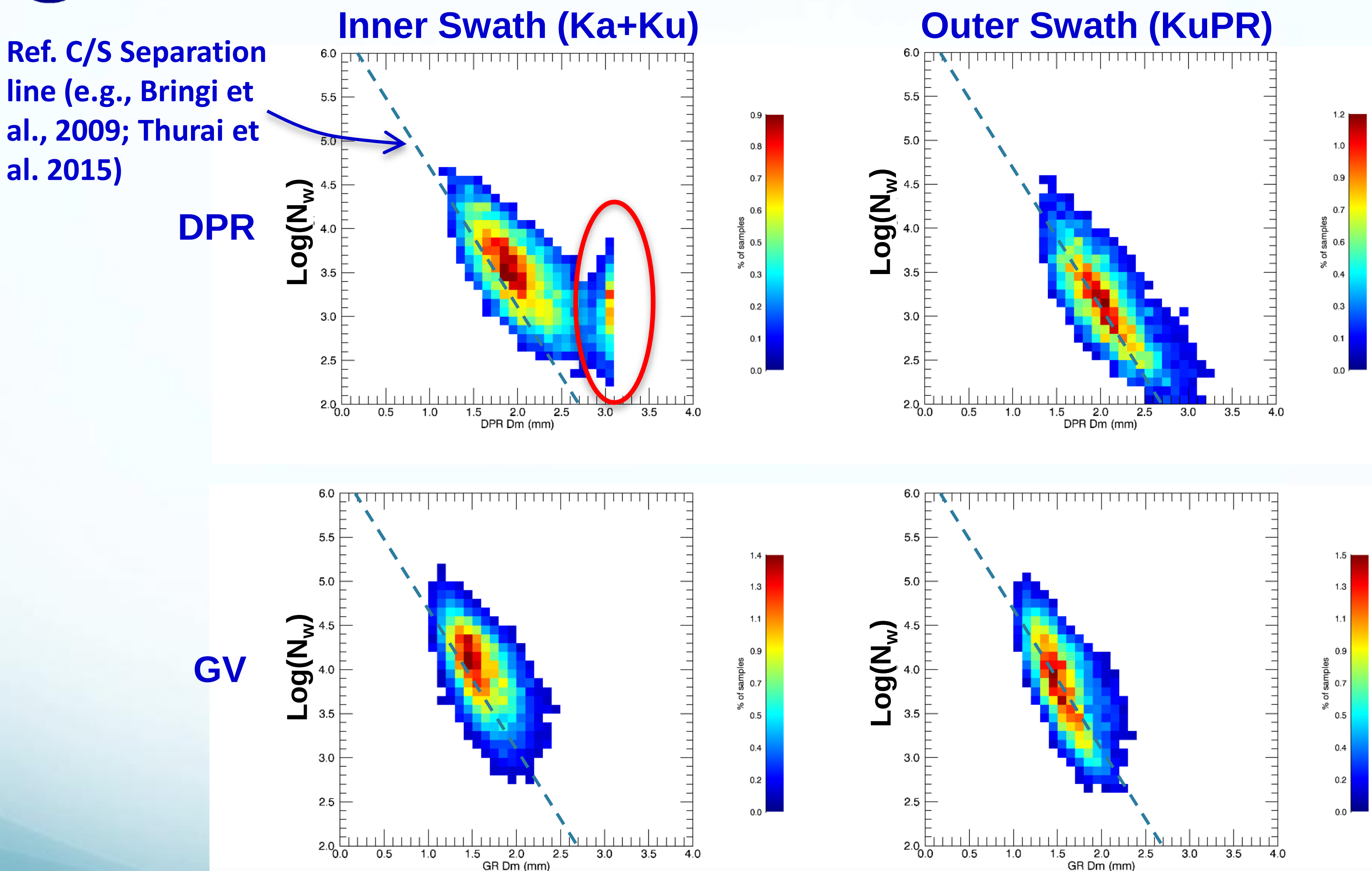
L1 DSD: DPR MS Version 4, Version 5 vs. GV Radar D_m



<u>L1 science requirement: Satisfied as a whole</u>. However, stratiform samples dominate and V5 inner swath of NS (MS) possesses an increasingly positive bias in D_m relative to GV;

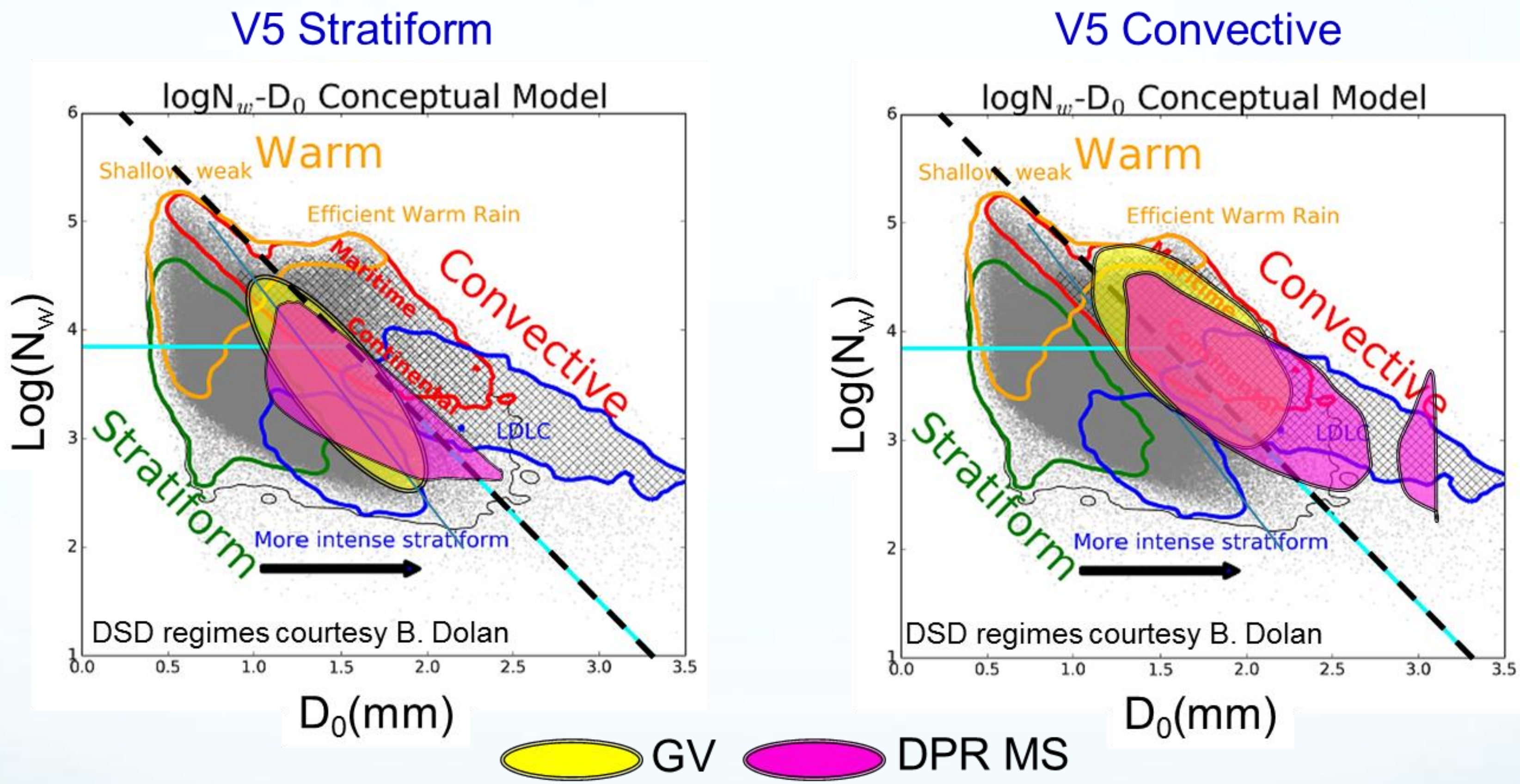
2ADPR Convective D_m in V5 deviates more from GV and <u>secondary mode in convective D_m more pronounced at large values of DPR D_m</u> (?)

2ADPR Convective N_w vs. D_m against GV Radar



- Dm offset results in lower N_w in DPR retrievals and mode in *inner* dual-freq. swath
- Differences marked between *inner* (DPR) and *outer* (2AKu) retrieval swaths
- Slope of Nw vs. Dm is reasonably similar between retrievals and GV pol relationship

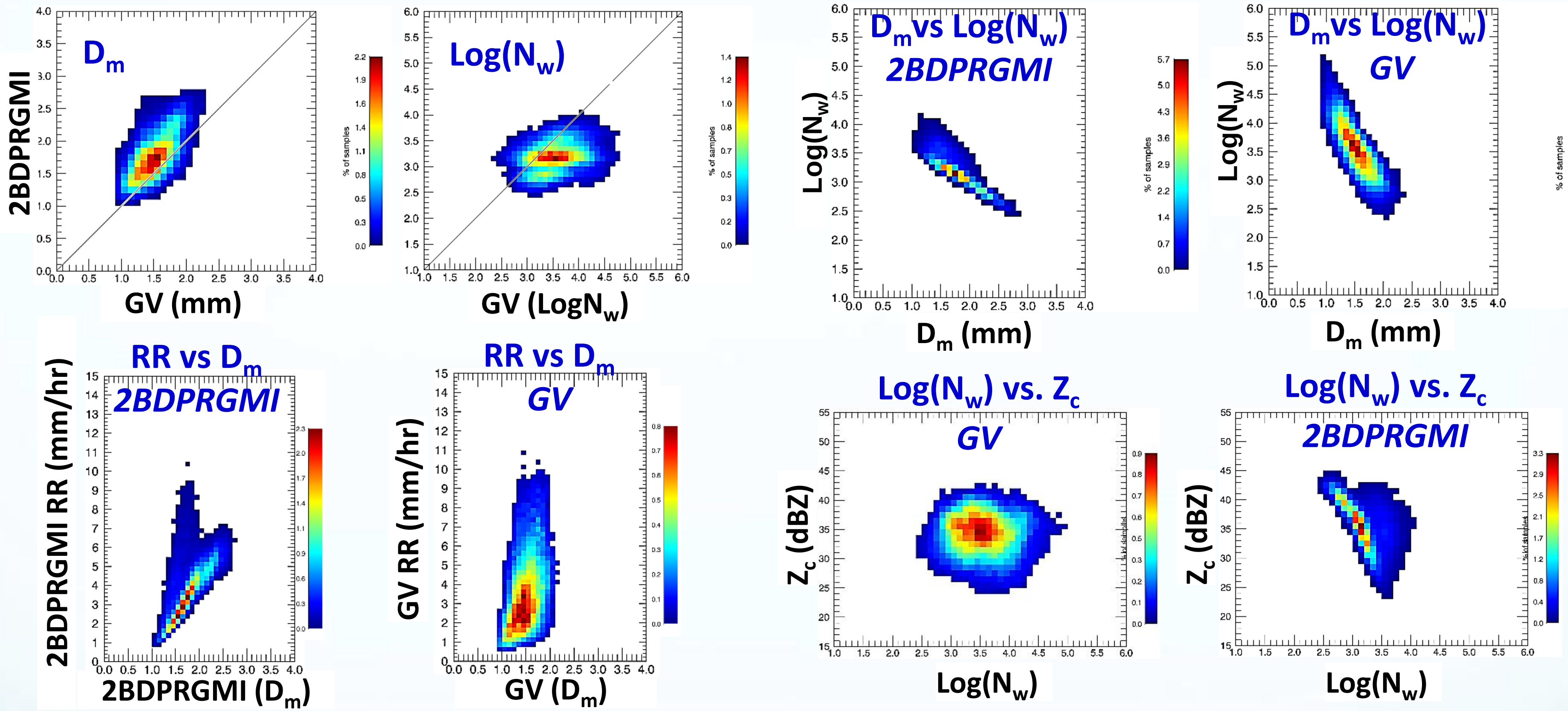
DPR and GV in Disdrometer Space D_m and N_w

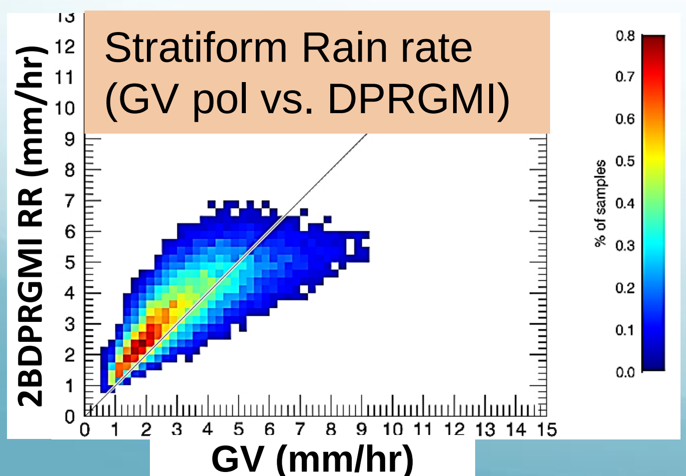


- V5 fits GV sample space (*Assuming* $D_m \approx D_0$); behavior qualitatively similar to GPM GV Radar
- Shift to larger D_m and smaller N_w relative to GV; secondary mode at large D_m

LogN$_w$-D$_0$ conceptual model via Dolan et al., 2017, JAS (submitted)

2BDPRGMI: MS Swath with GV (DSD, Rain, Z…)





- Modes in the 2BDPRGMI DSD (N_w?).
- In aggregate 2BDPRGMI produces a footprint rain rate similar to GV (GV-pol, and the MRMS!)

Summary

Approach:

- Polarimetric radar-based DSD retrievals (D_m, N_w) developed using 2DVD data for multiple rainfall regimes; scale translation to GPM satellite footprints/swaths.
- VN architecture for comparing GPM Core satellite DPR to GV on CONUS scale

Result:

- GPM Level 1 Requirements on D_m (+/- 0.5 mm of GV) are satisfied relative to GV measurement;
- Dm positive bias- accentuated in convective precip; N_w in DPR somewhat similar to GV but responds to Dm bias; Combined-Algorithm N_w- odder behavior compared to GV.
- Sensitivity of comparisons to rain type (Convective vs. Stratiform) and swath (e.g., inner Ka/Ku vs. outer KuPR, Combined MS)- algorithms/sampling vs. physics?

Moving ahead:

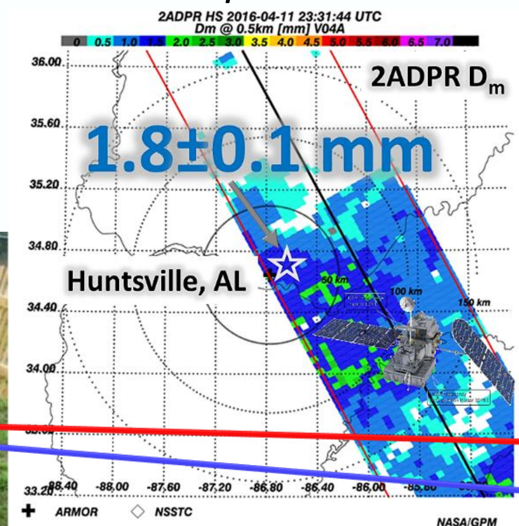
- Further analysis work to parse/isolate DSD behavior as a function of 3-D GPM and ancillary observables to guide algorithm approaches (e.g., μ, PIA, N_w selection in Combined algorithm, ε and associated parameter behavior in DPR/KuPR algorithms….)
- Further GV work on defining the DSD for light rain/small D_m- Generalized Gamma approach?

EXTRAS

Next: How do we handle light rain DSD?

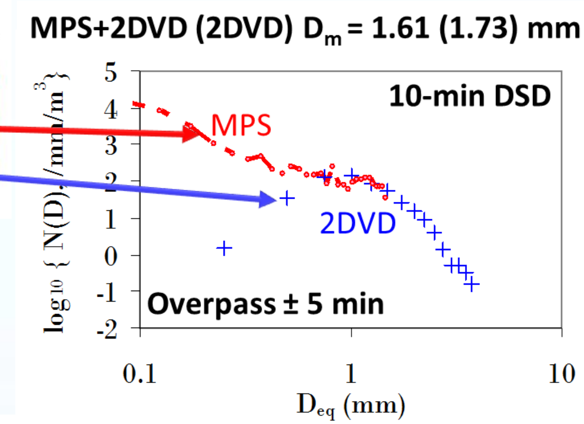
Do current DSD assumptions for GPM adequately represent the small rain drop sizes?

GPM dual-frequency precipitation radar (DPR) swath as it samples rain over Huntsville disdrometers



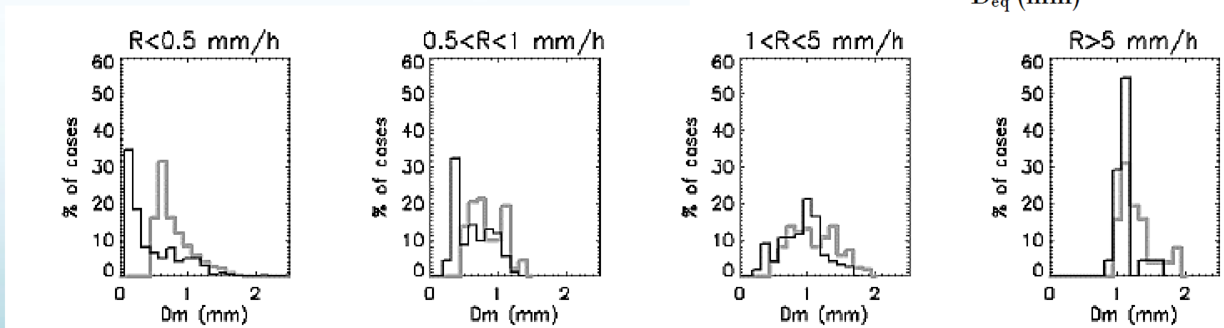
Right answer ….right reason**?**

DSD measured by GV



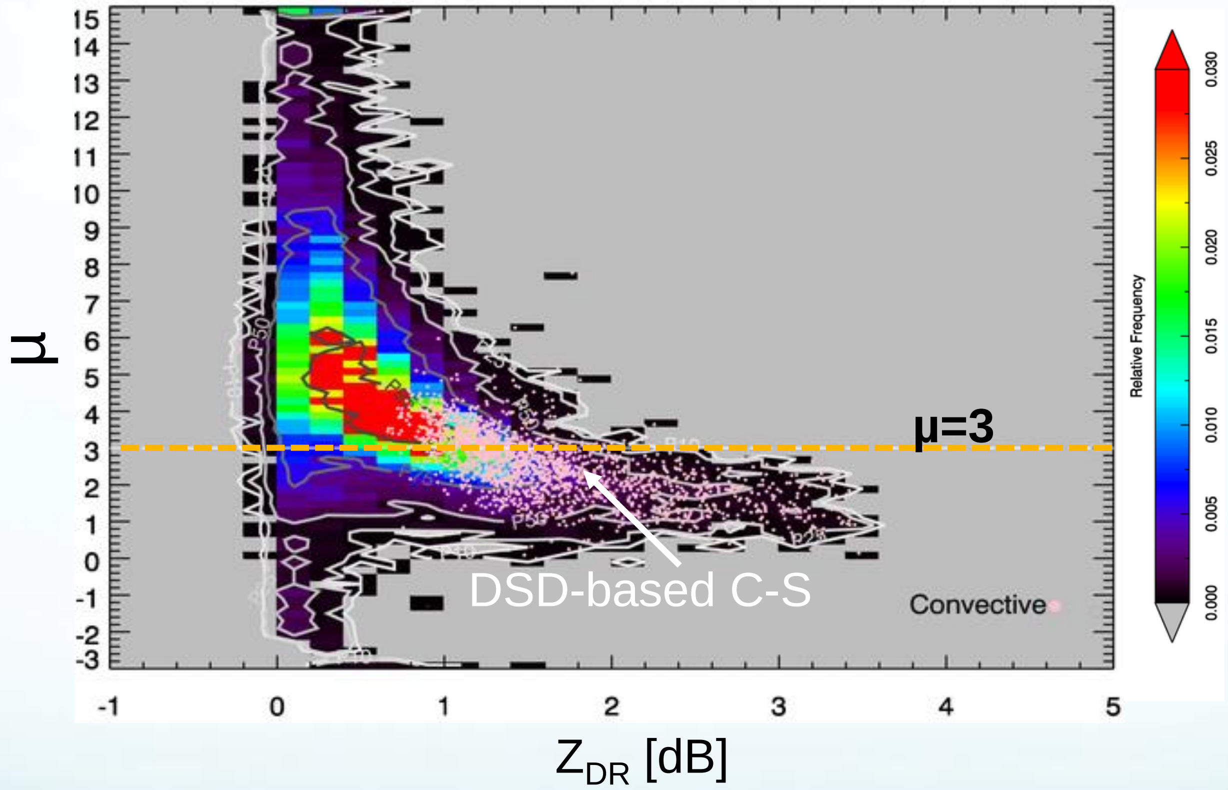
We do not properly represent the small-drop end (< 0.7 mm) of the drop size distribution-

Likely important for light rain estimation.



Reference: Thurai et al. 2017, JAMC

μ = 3 ?



Convective (stratiform) μ almost always < (>) 3 in MC3E and Alabama 2DVD data [DPR μ=3, Combined μ=2]