Use of Polarimetric Radar for Evaluating GPM Satellite-Based Retrievals of the Rain Drop Size Distribution

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Outline

- **Context: GPM Requirements**
- **Approach, Methods, Data**
- **Verification of L1 requirement**
- **Convective "drill down"**
- **Summary**

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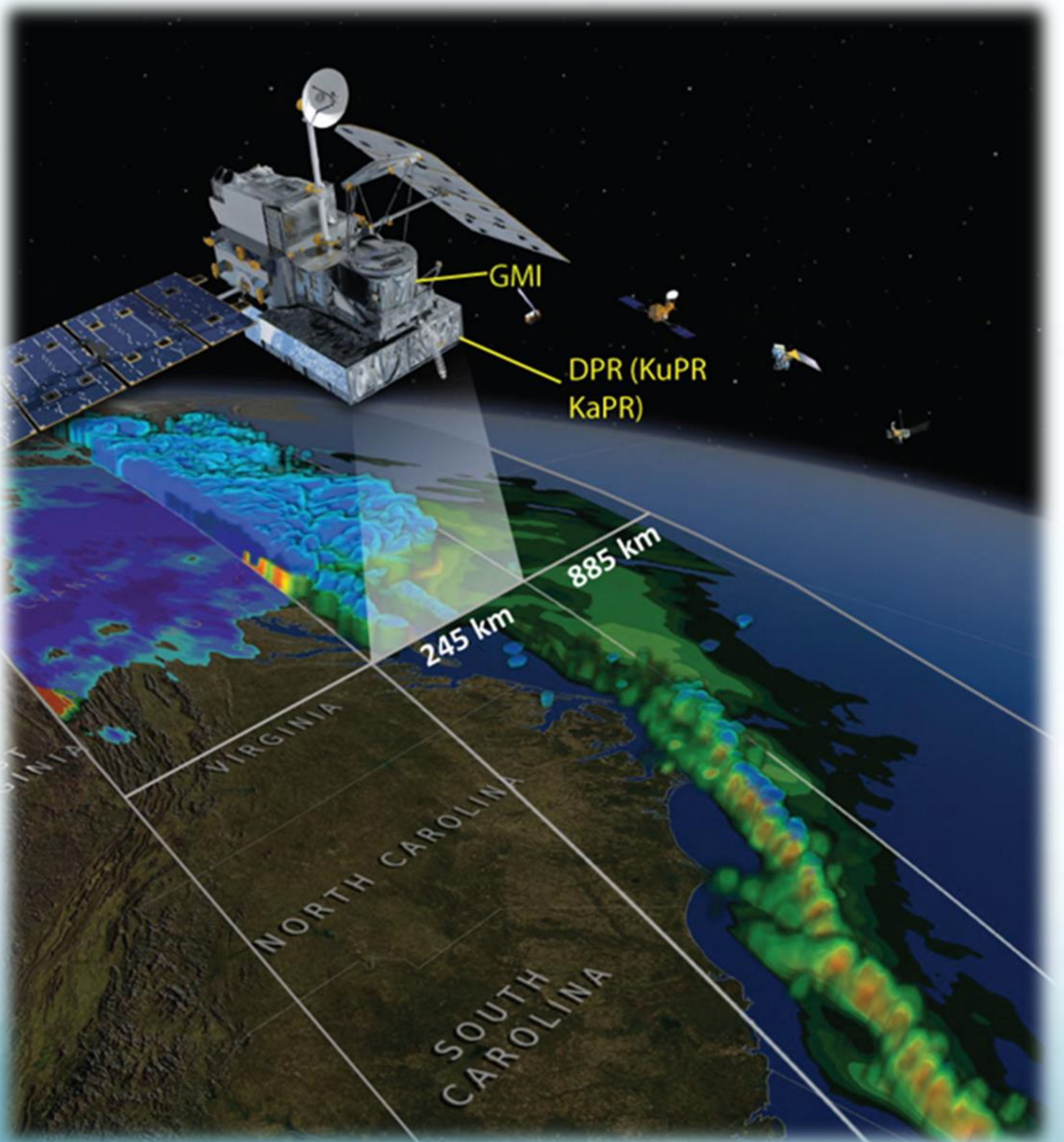
Context: GPM Core Observatory Science Requirements



GPM "Core" L1 Science Requirements

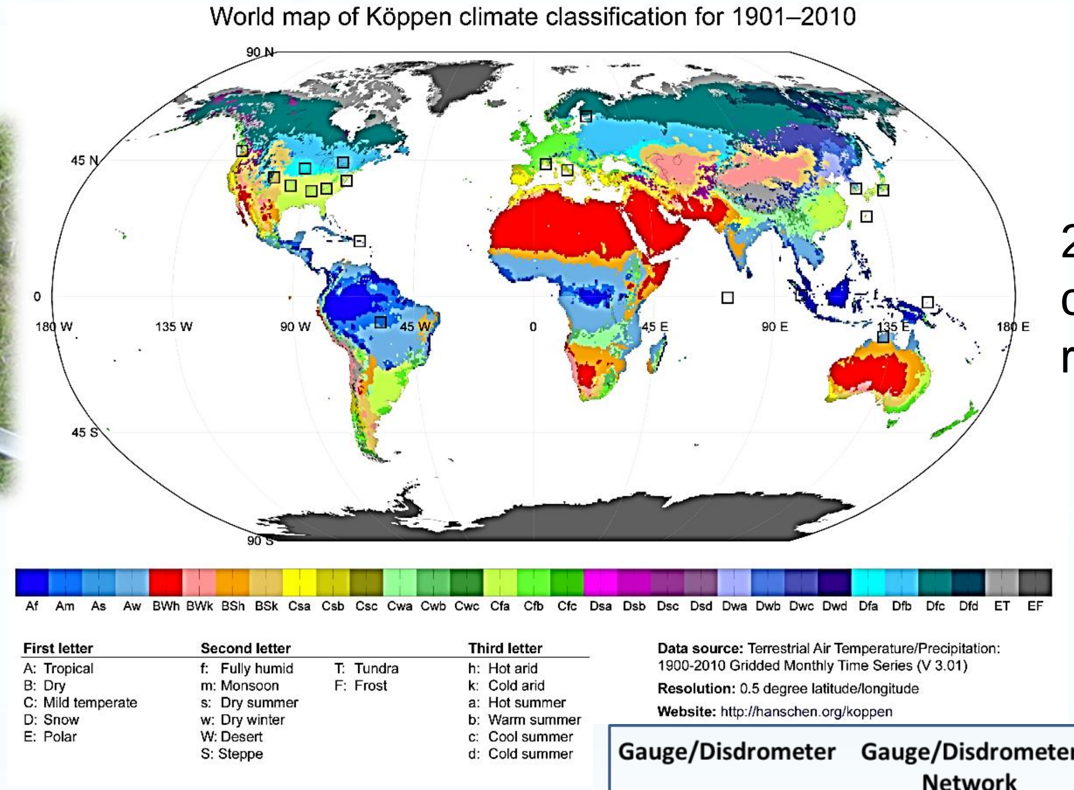
- DPR: *quantify rain rates* between 0.22 and 110 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 5 km*.

- 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 *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*

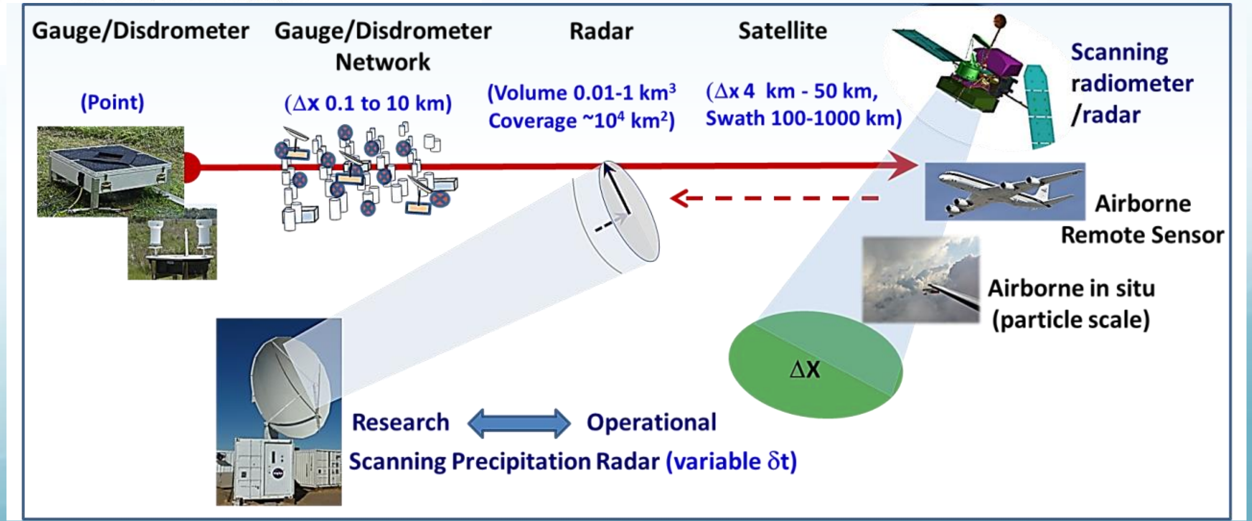
- **Core observatory estimation of the Drop Size Distribution (DSD)** ***D_m to within +/- 0.5 mm*****. [note- no N_w requirement]**

Validating the GPM DSD Requirement: Overarching Philosophy

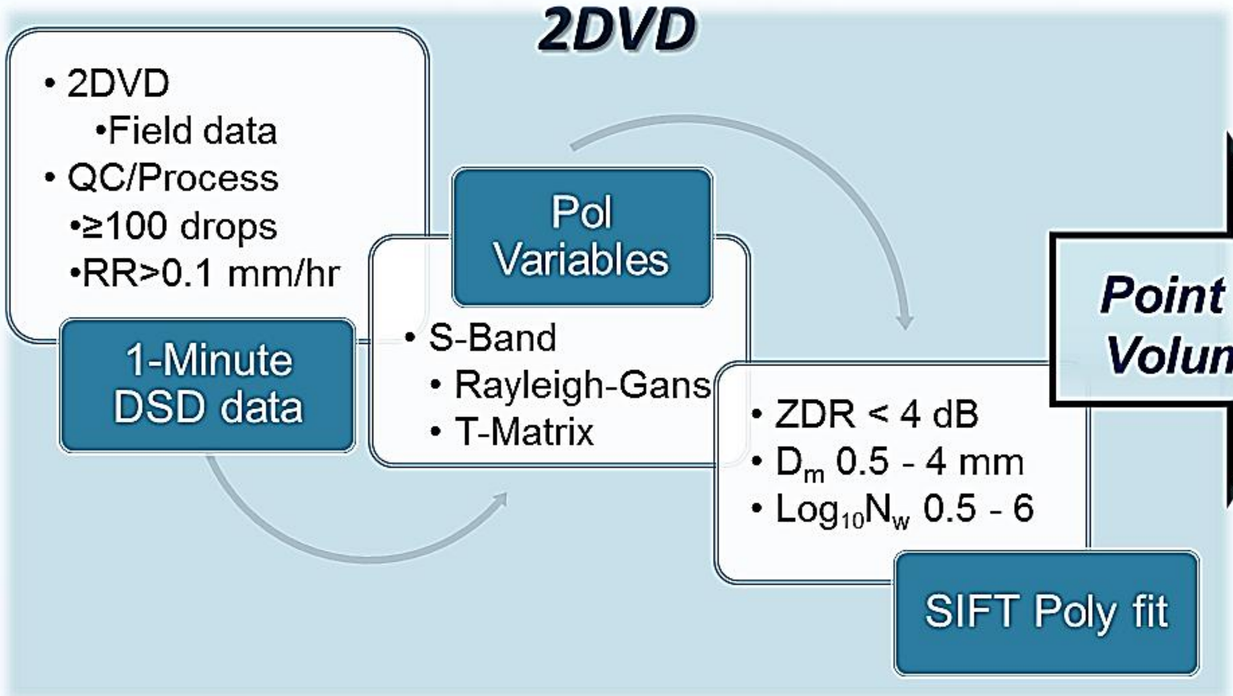


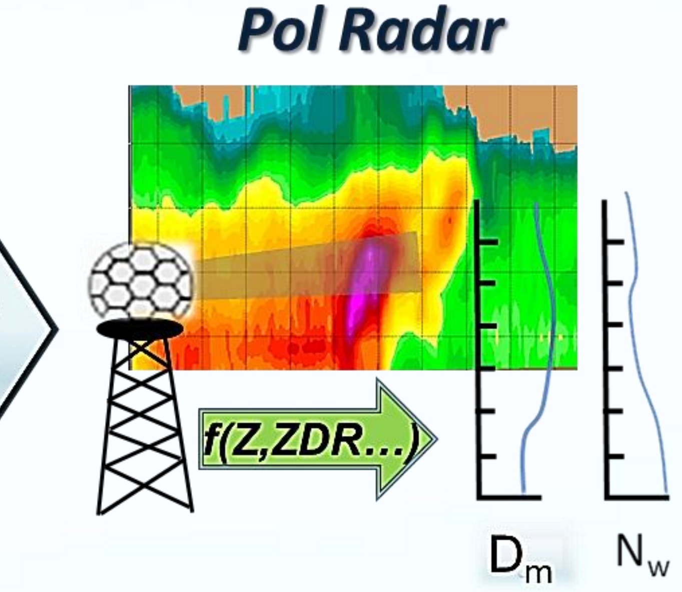
2D Video disdrometer data collected at numerous locations, regimes, and point scales……

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



Approach: 2DVD to Radar





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

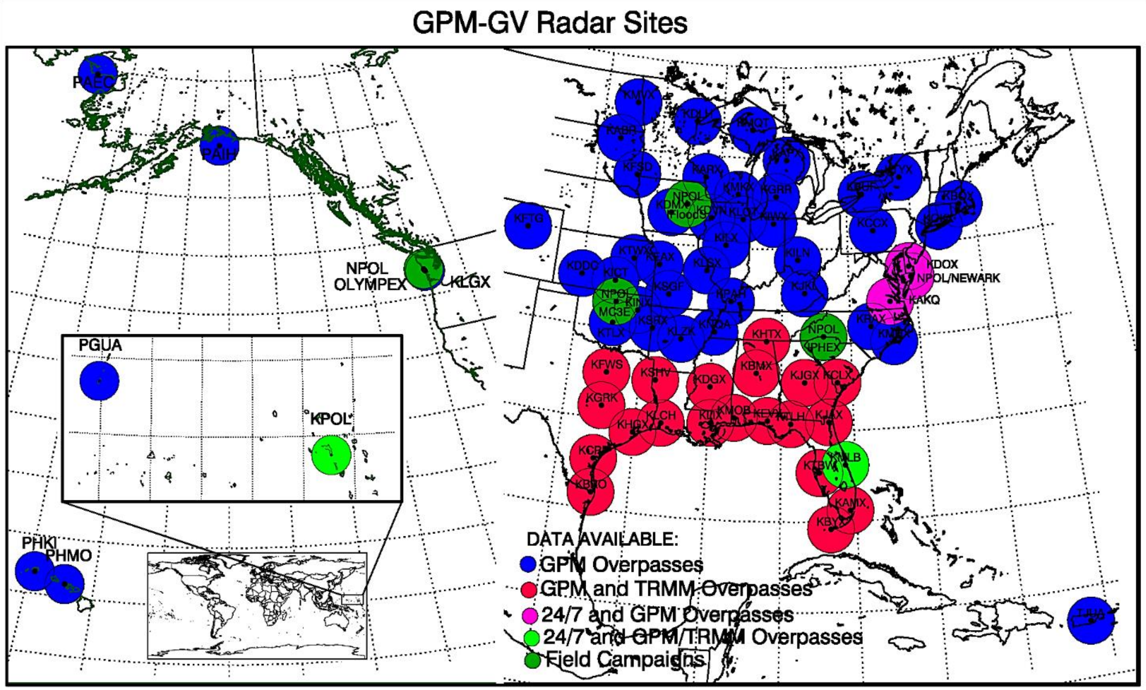
$N_w = a\, Z\, D_m^{\,b}$

- Empirical models developed for NASA field campaign "regimes" (Oklahoma, Iowa, Alabama, Mid-Atlantic Coastal, Washington Coast, Appalachians/Piedmont….)

- Aggregated to make "***ALL-regimes***" for U.S. continental-scale statistical verification (> 200,000 minutes used)

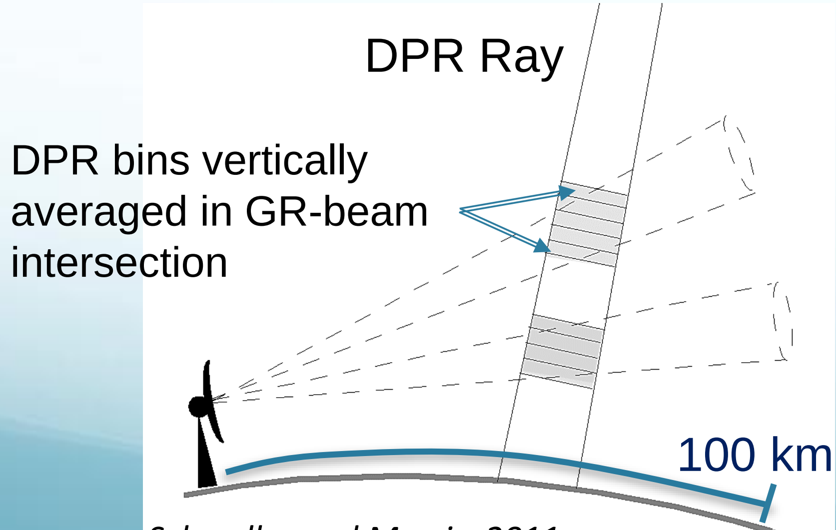
    - ***"ALL"* DSD *model-fit* relative errors: *BIAS < 10%, MAE < 15%***

Approach: Radar to GPM using Validation Network (VN) Radars



88Ds, NPOL, KWAJ

Dual-pol quality-controlled moments and diagnostics (DSD, rain rate, HID etc.) computed from network radar datasets



Schwaller and Morris, 2011

VN Matching

DPR Range gates/footprints within 100 km of a given VN radar geometrically volume-matched to intersecting DPR rays

Products stored (e.g., select DPR variables, Polarimetric moments, ***DSD***, HID, RR…)

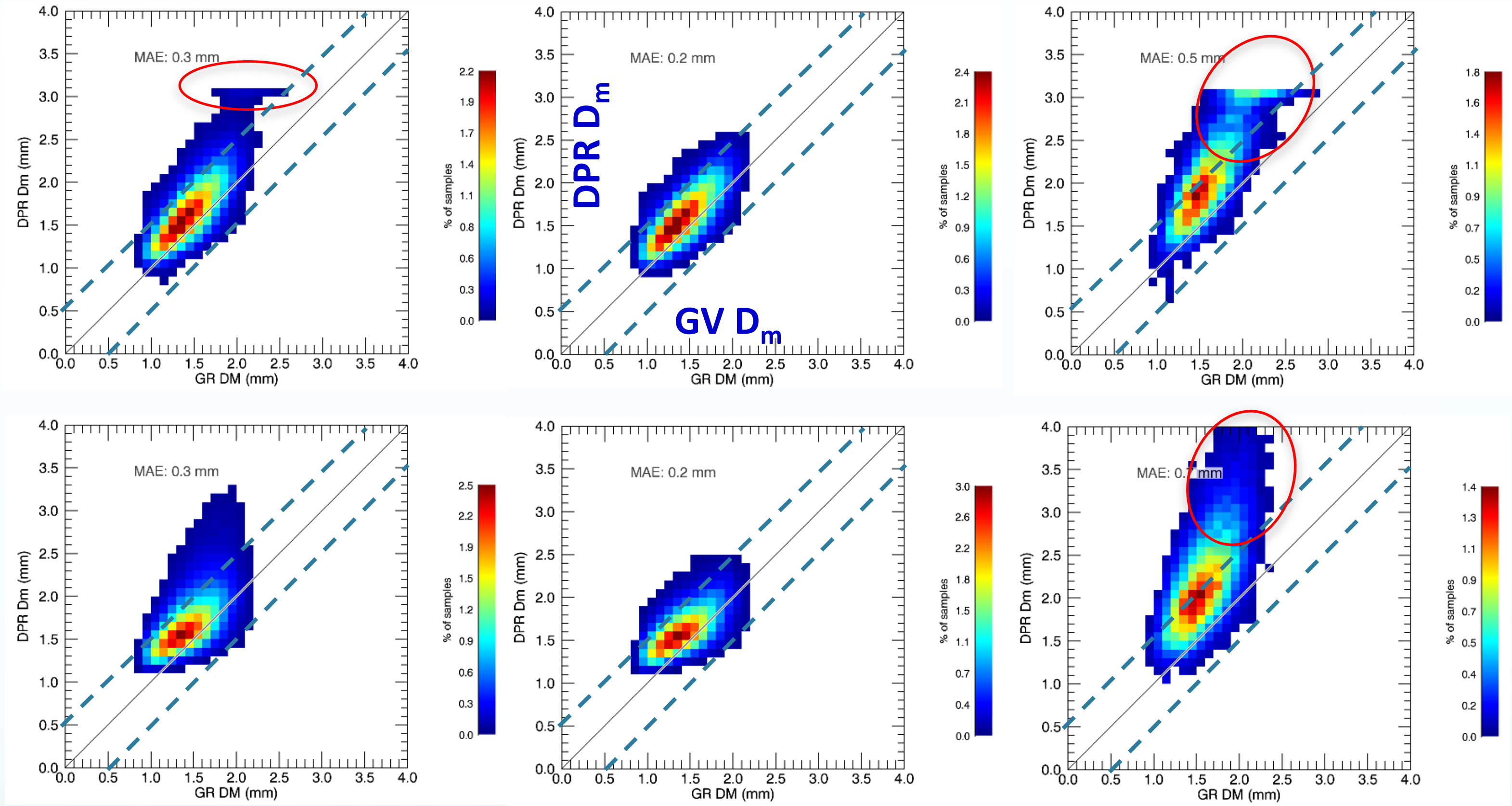
L1 Requirement DSD: Continental Scale VN-GPM Comparisons

DPR MS, 2AKu (DPR NS) V5 D_m vs. GV Radar D_m

All | Stratiform | Convective

DPR MS

2AKu/DPR NS



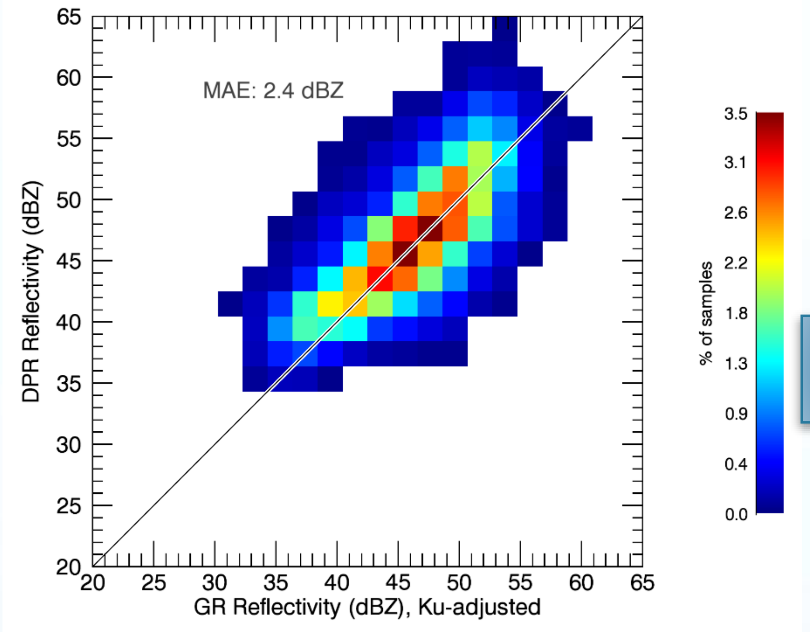
Science requirement generally met.....

- **Core observatory radar estimation of the Drop Size Distribution (DSD)- specifically, *D_m to within +/- 0.5 mm***

- In stratiform precipitation, V5 DPR is about ~0.2 mm higher than GV (= ~0.2 dB cold bias in ZDR), but............
- 2ADPR Convective D_m bias is a problem (D_m ceiling at 3 mm in MS an artifact)

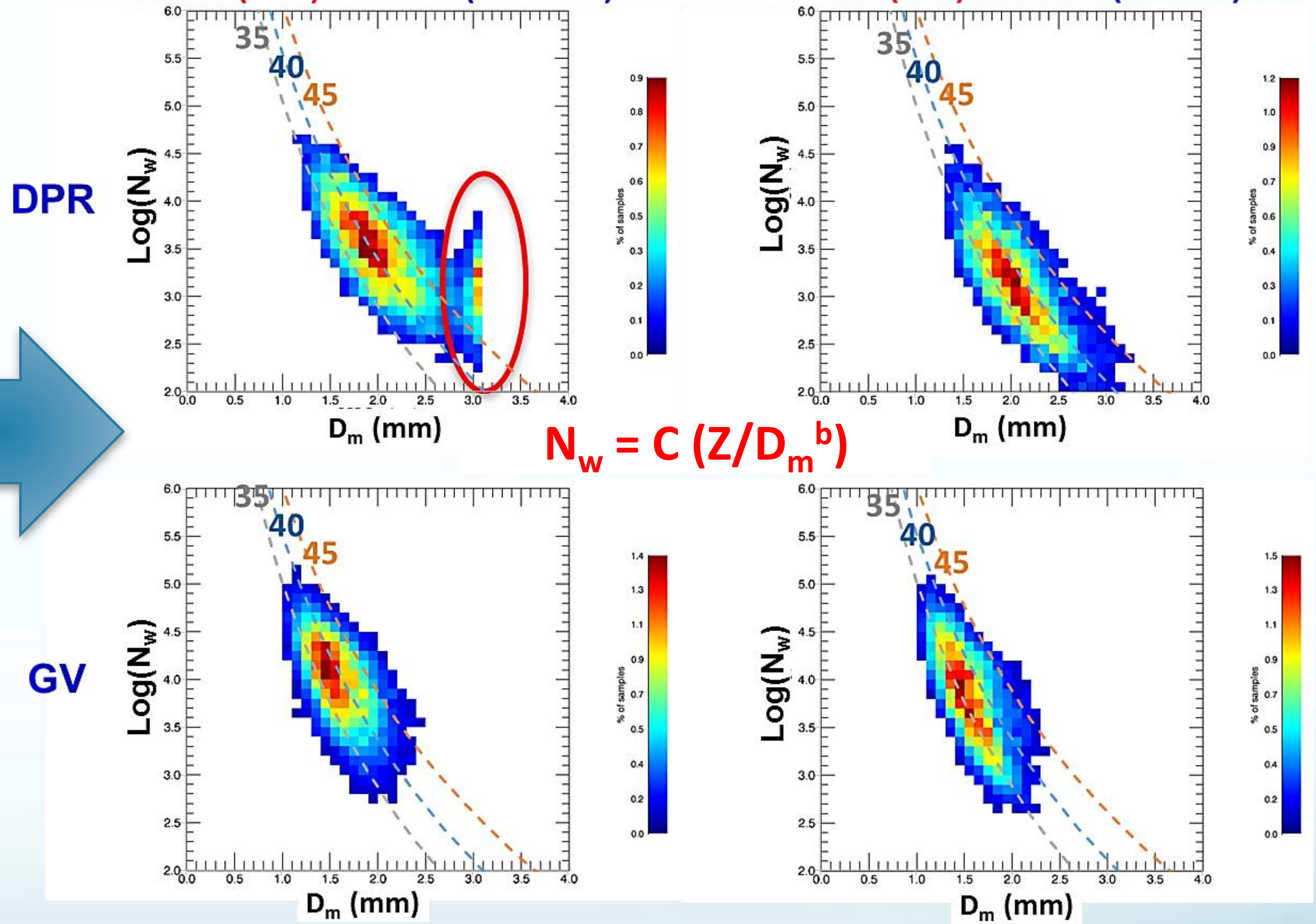
Closer look at V5 DPR MS/NS(KuPR): Convective N_w vs. D_m against GV

GV Z vs. 2AKu Z



For convective samples in rain (here for 2AKu D_m > 2.5 mm), Z GV and 2AKu PR are very similar

Inner (MS) Swath (Ka+Ku) | Outer (NS) Swath (KuPR)

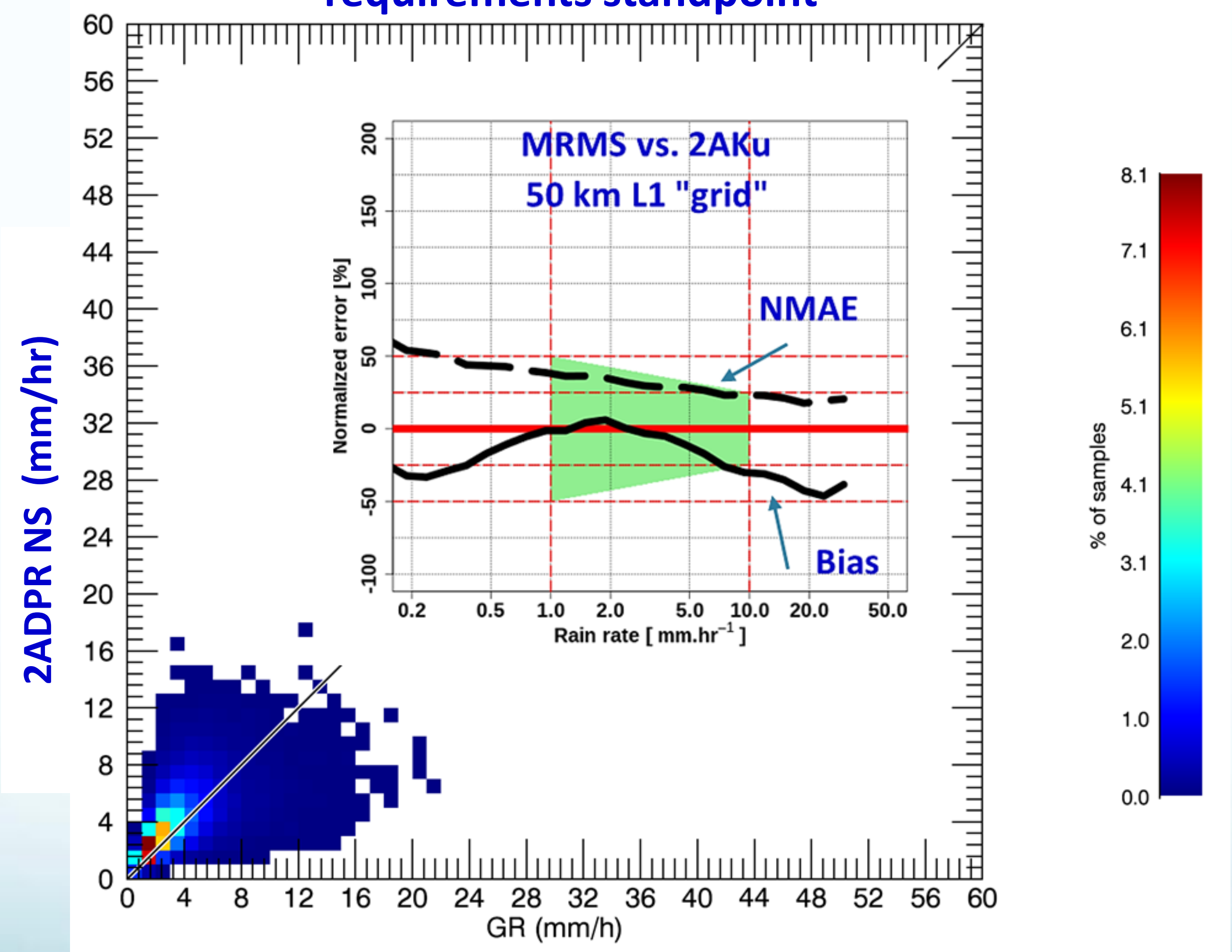


$N_w = C\,(Z/D_m^{\,b})$

- DPR D_m bias implies lower N_w vs GV along Z-isopleths; bias is obvious but trend is similar (physics)

Impacts of Increasingly Positive D_m Bias in Convective Rain?

Performance reasonable from L1 science requirements standpoint



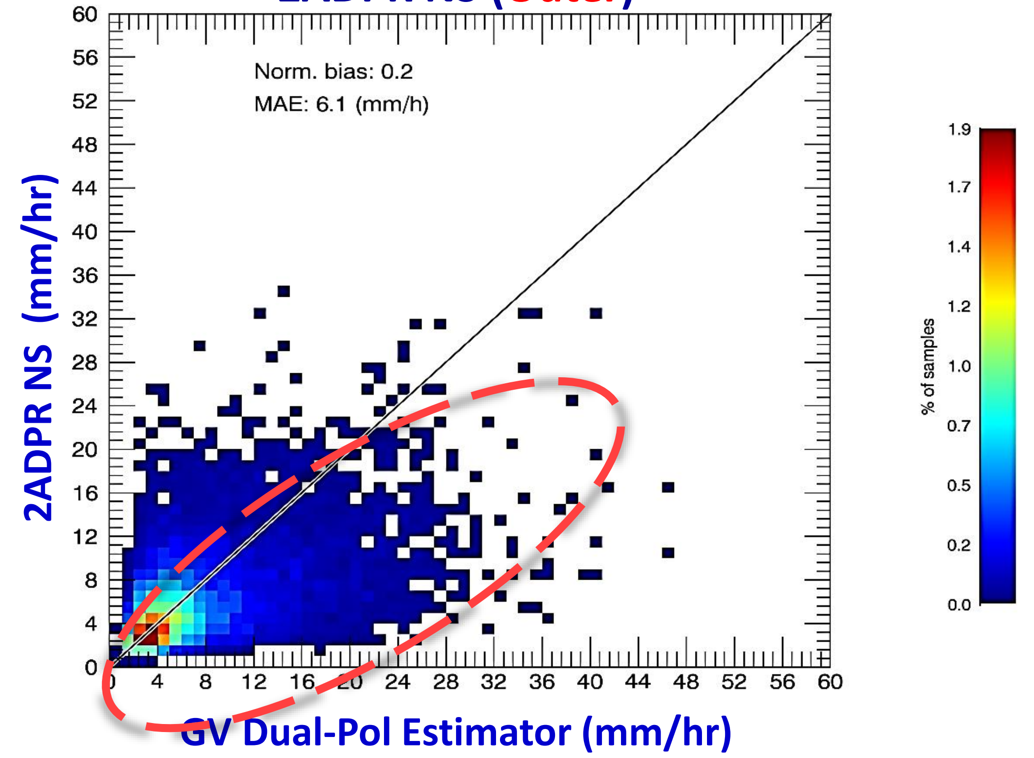
Recall 2AKu = Single Freq. Retrieval
2ADPR-NS "Outer" = 2AKu

But.........

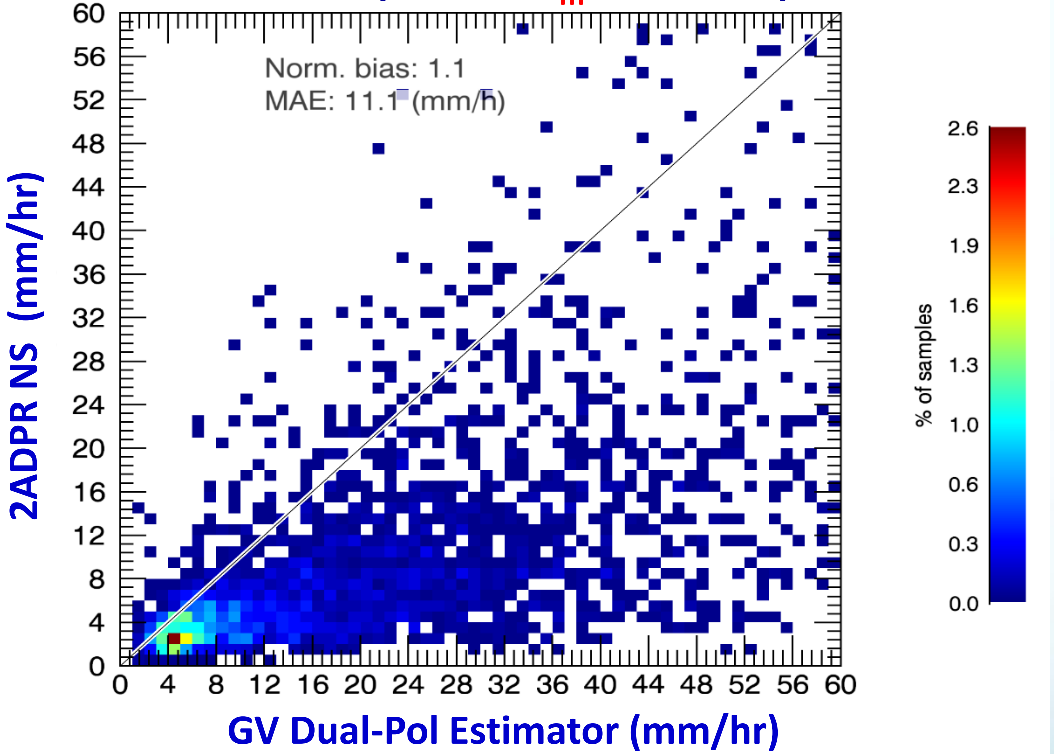
Impacts of Increasingly Positive D_m Bias in Convective Rain?

Marked low bias against GV rain rates when DPR-Identified large drop regimes occur

2ADPR NS (Outer)

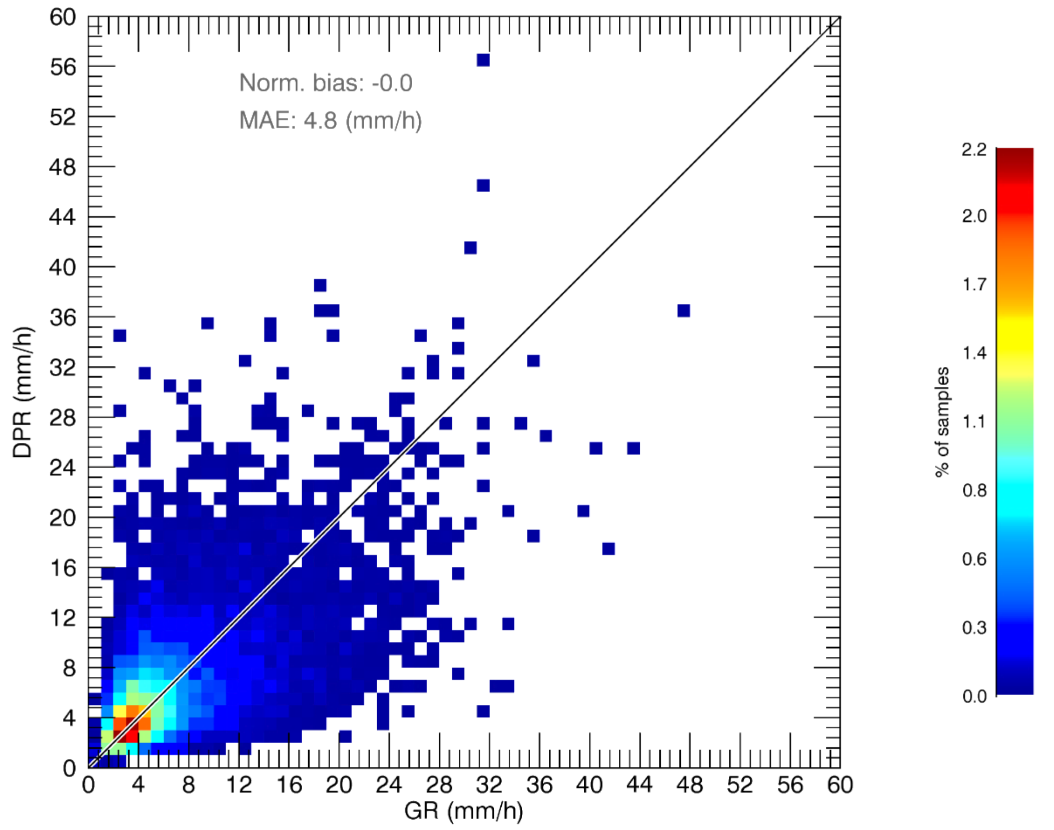


2ADPR NS (Outer- D_m > 2.5 mm)



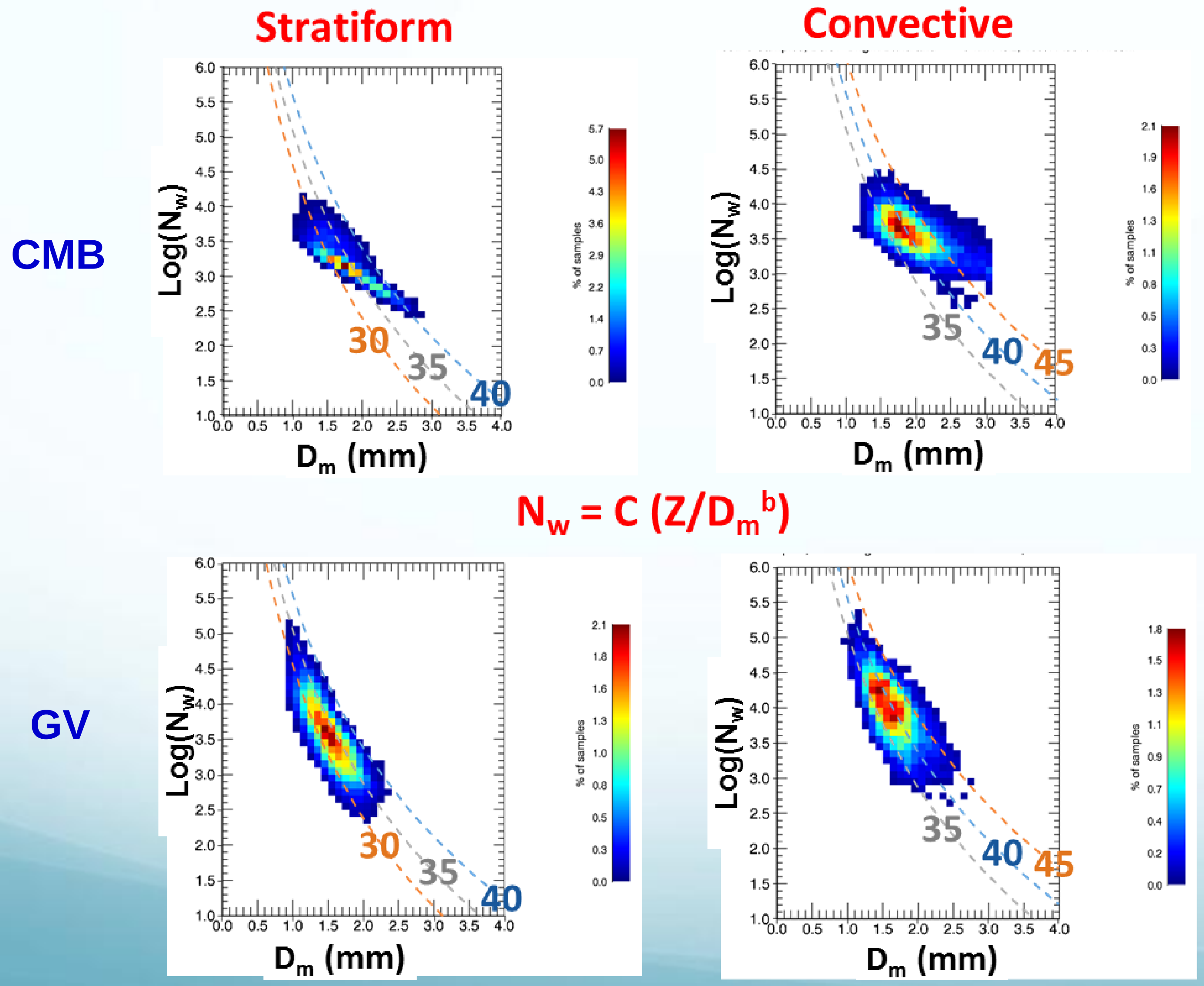
DSD "Big D_m" Impact

Tail of "big-D_m" data points makes up ~12% of the convective sample……. Worth fixing/examining more?



Yes.

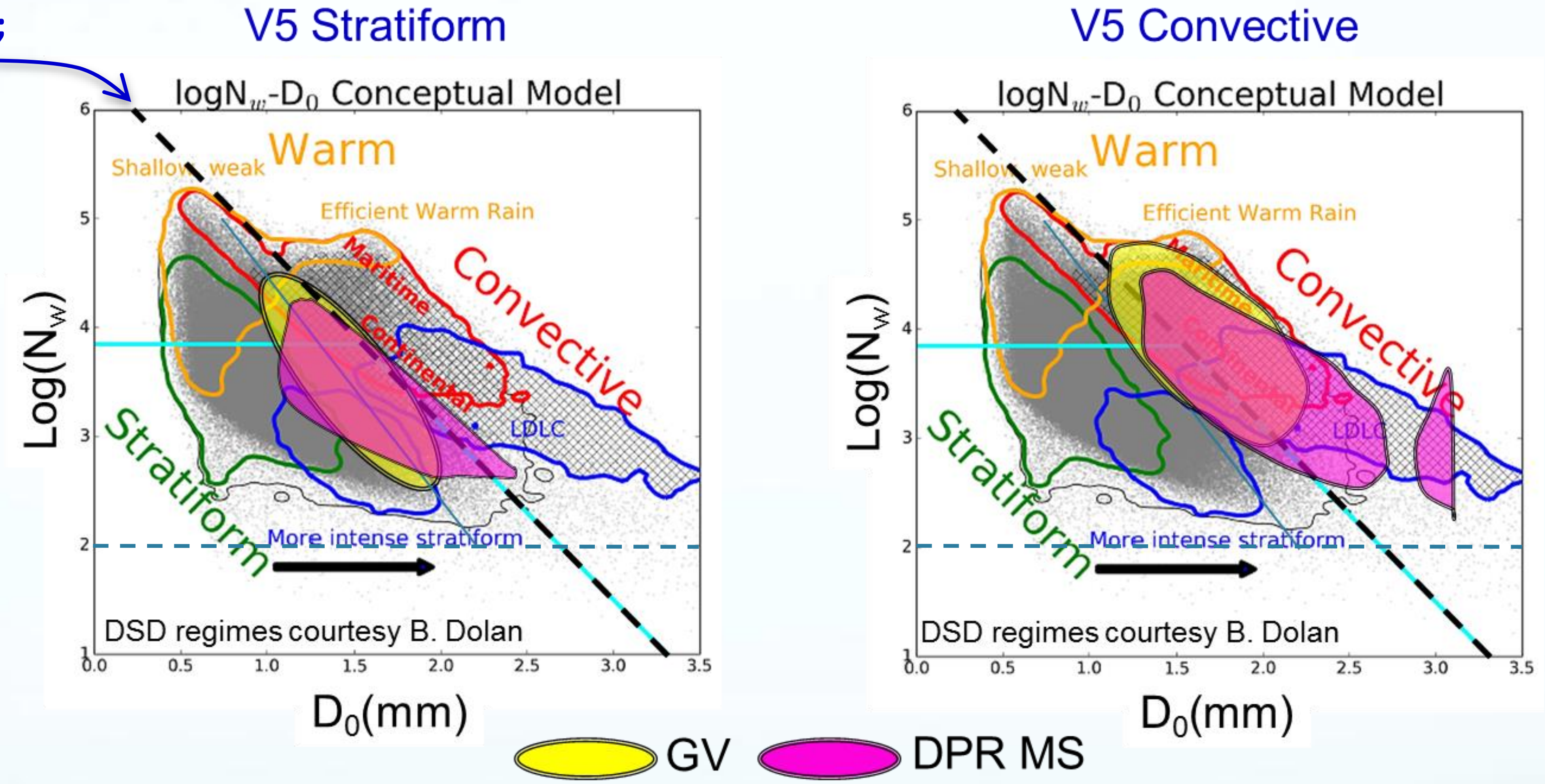
Combined Algorithm: MS Swath with GV (DSD, Rain, Z…)



- V5 N_w vs. $f(D_m,Z)$ trend (slope) is different from GV and DPR for approximately the same precipitation sample……..
- N_w not as tightly constrained in V5
- New results (M. Grecu) that test more realistic N_w-D_m constraints (similar to GV) suggest improvement- especially in reducing single frequency algorithms positive bias and random error in rain rates between 1-10 mm/hr.

DPR and GV in Disdrometer Space D_m and N_w

C/S Separation line
(e.g., Bringi et al., 2009;
Thurai et al. 2015;
Thompson et al, 2015)



- V5 MS fits GV sample space (*Assuming* $D_m \approx D_0$) physical behavior qualitatively…..though, overlap between C/S exists…………sensitivity to how C/S is partitioned

Also see Dolan et al., 2017, JAS (submitted)

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.

Results:

- GPM Level 1 Requirements on D_m (+/- 0.5 mm of GV) satisfied
- DPR D_m positive bias relative to GV- enhanced in convective precip; N_w in DPR somewhat similar to GV but affected by D_m bias; Combined-Algorithm N_w- different behavior……..
- KuPR "big-D_m" bias noticeably impacts convective rainfall estimate (underestimate) relative to GV.
- Sensitivity to rain type (Convective vs. Stratiform) and swath (e.g., inner Ka/Ku vs. outer KuPR, Combined MS).

Moving ahead (prior to V6):

- Further analysis work to isolate *details* of DSD behavior as a function of 3-D GPM and ancillary observables to guide/test algorithm approaches (R-D_m, epsilon……)
- Further work to define the DSD for light rain/small D_m