A RADAR-BASED EVALUATION OF GPM RETRIEVALS OF THE RAIN DROP SIZE DISTRIBUTION

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Outline

- Context
- Approach
- DPR – Issues in convection
- Combined - Different then GV *and* DPR
- Summary

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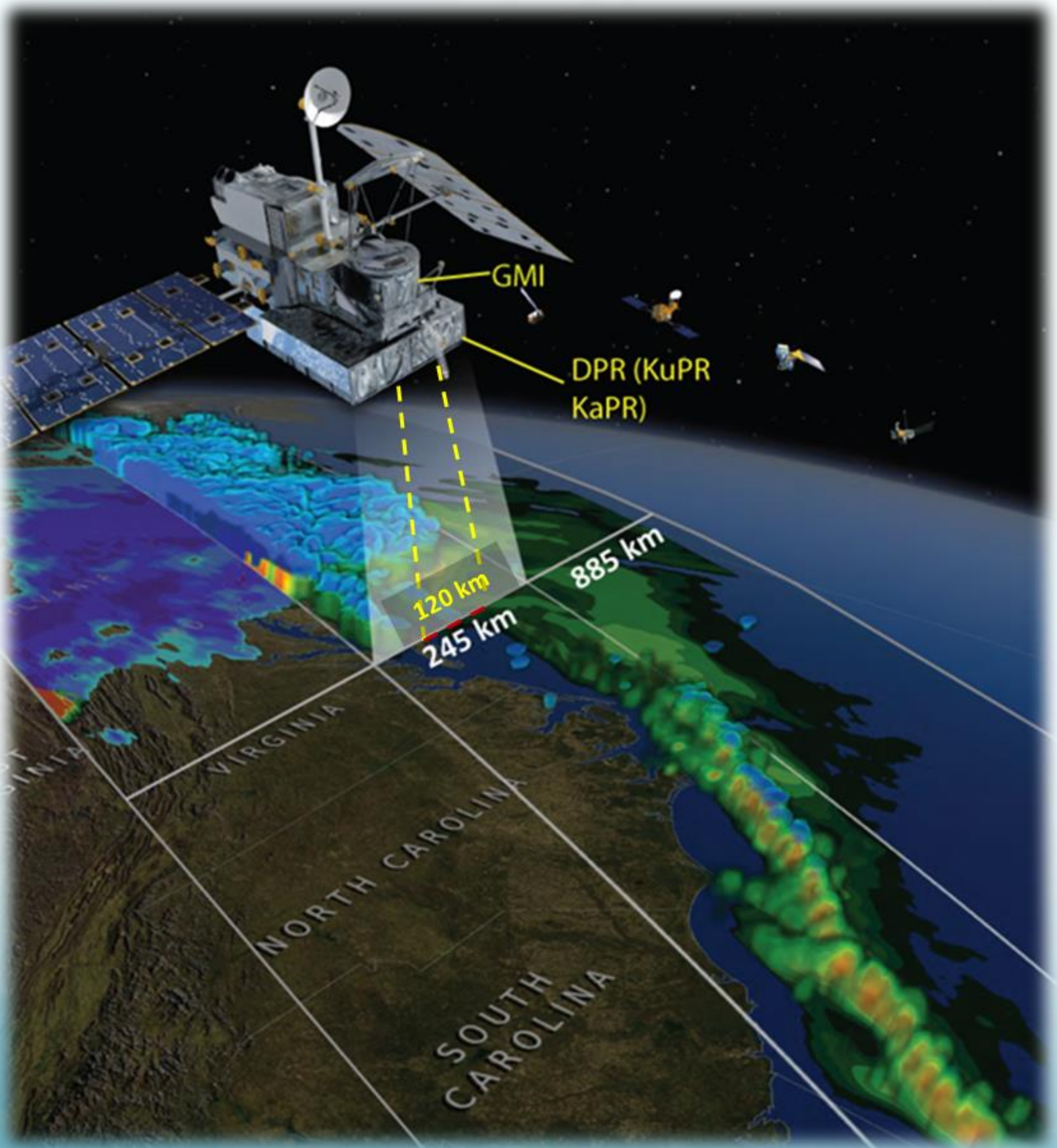
Context: DSD a fundamental GPM Core Observatory Science Requirement



GPM "Core" L1 Science Requirements

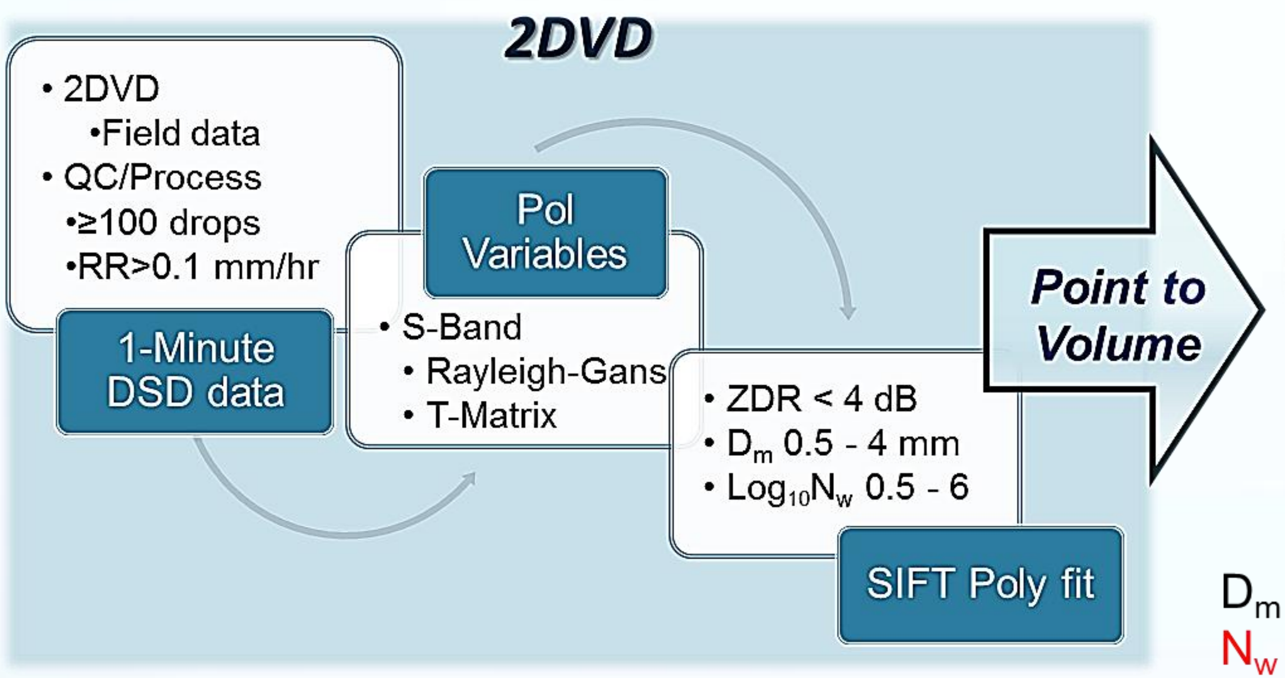
- DPR: *quantify rain rates* between 0.22 and 110 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 5 km*.

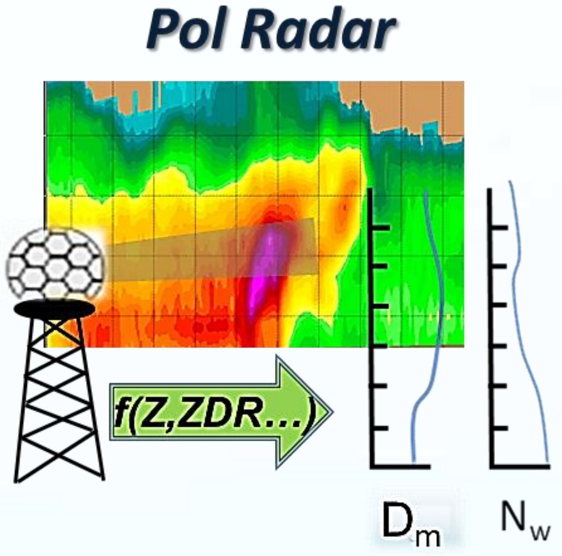
- GMI: *quantify rain rates* between 0.22 and 60 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 15 km*.

- 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]**

Approach: 2DVD to Radar, Radar to Satellite





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

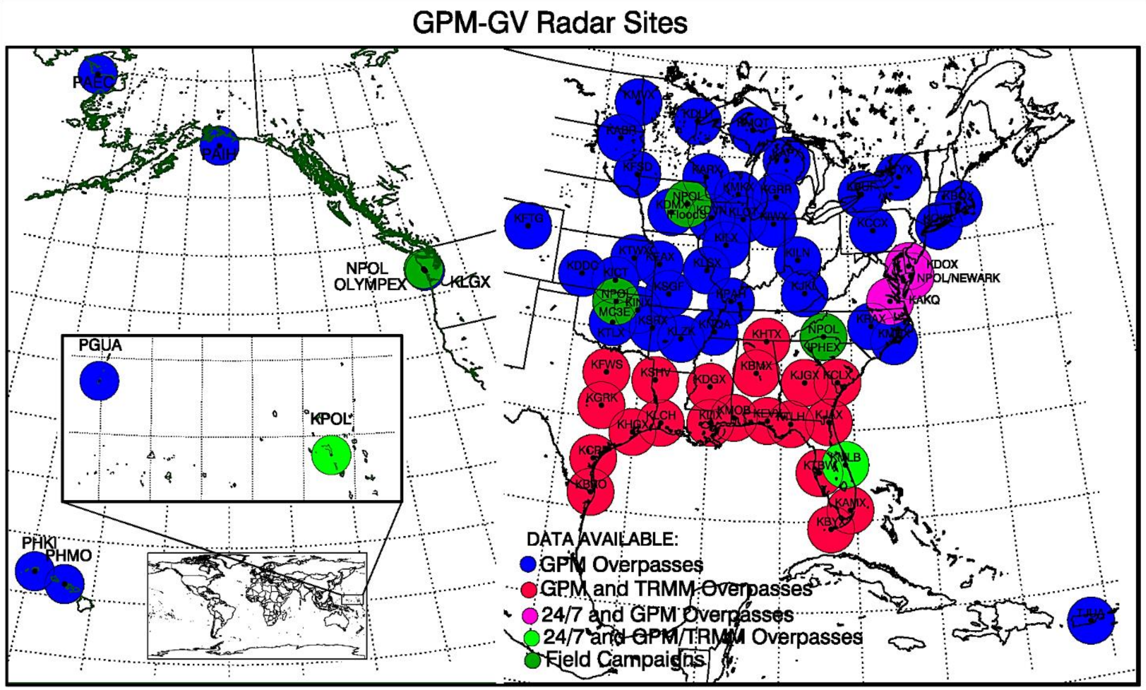
$N_w = a\,Z\,D_m^b$

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

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

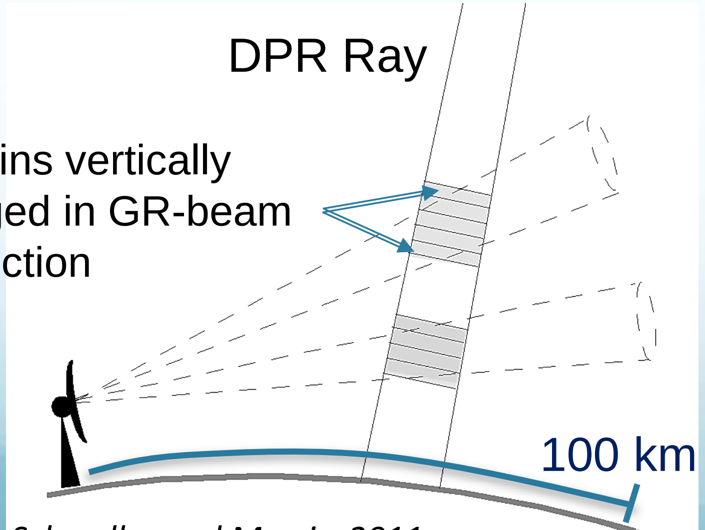
  - ***"ALL" DSD <u>model-fit</u> relative errors: BIAS < 10%, MAE < 15%***

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 ~70 network radars



Schwaller and Morris, 2011

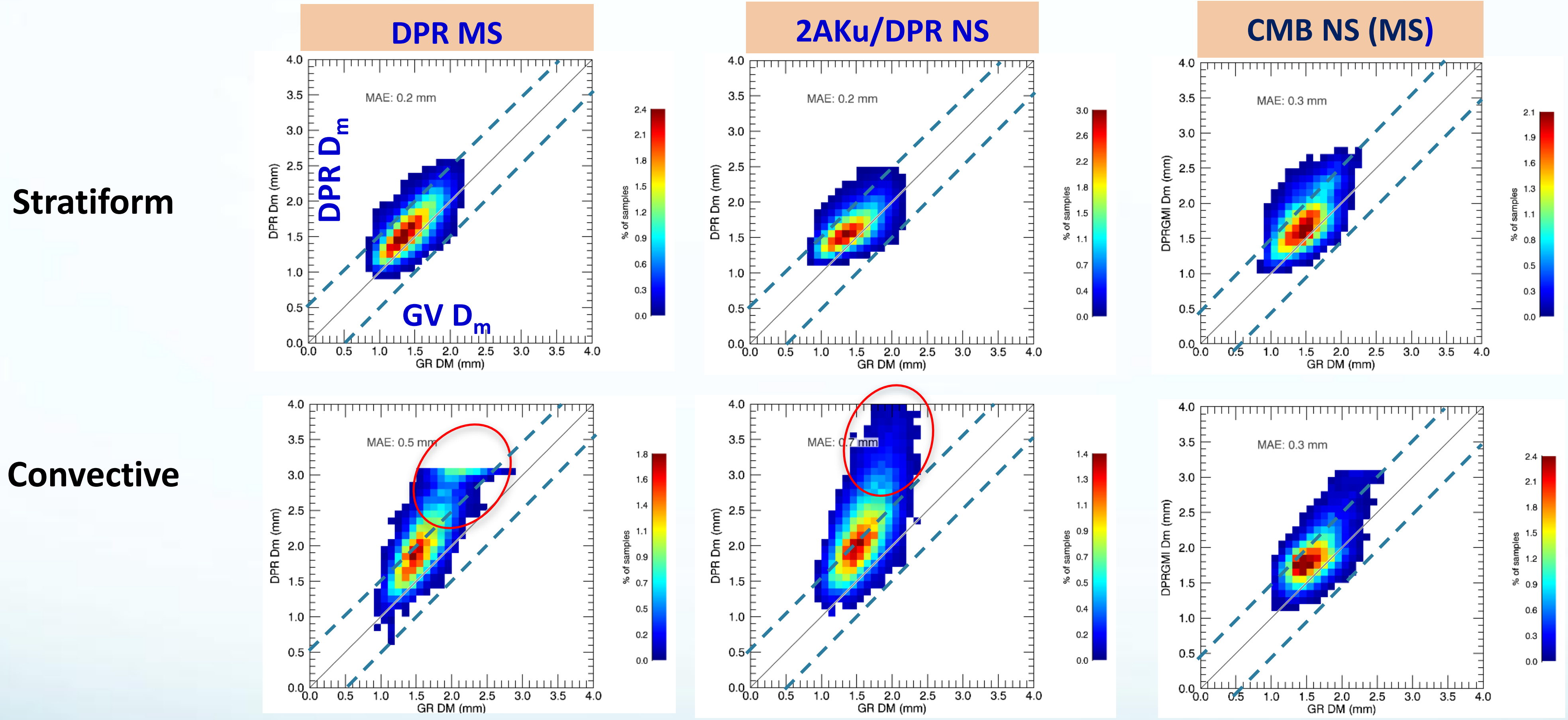
VN Matching

DPR Range gates/footprints within 100 km of a given radar geometrically volume-matched to intersecting DPR rays (> 5000 volumes since launch)

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

L1 Requirement DSD: Continental Scale VN-GPM Comparisons

DPR, 2AKu, CMB **V5 D_m** vs. **GV Radar D_m**

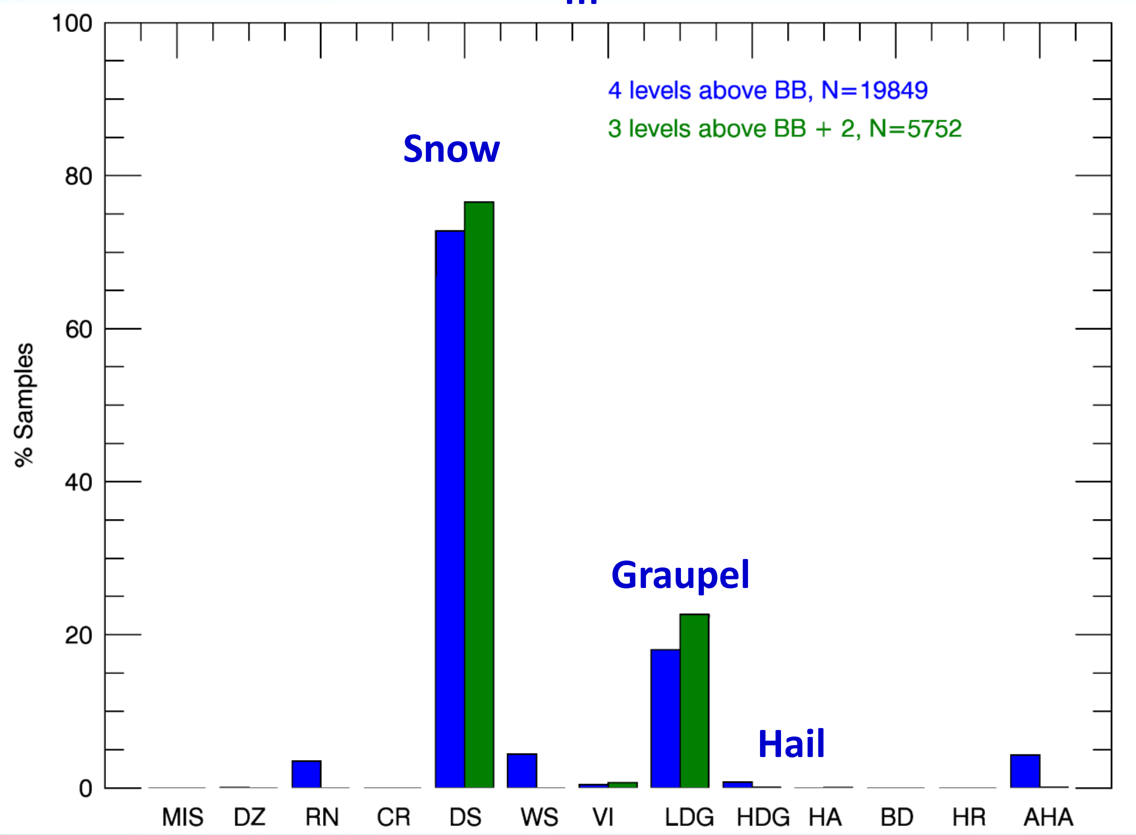


- L1 requirement met because it is driven by stratiform- about ~0.2 mm higher than GV but………….
- DPR Convective D_m bias is a problem (D_m ceiling at 3 mm in MS an artifact)

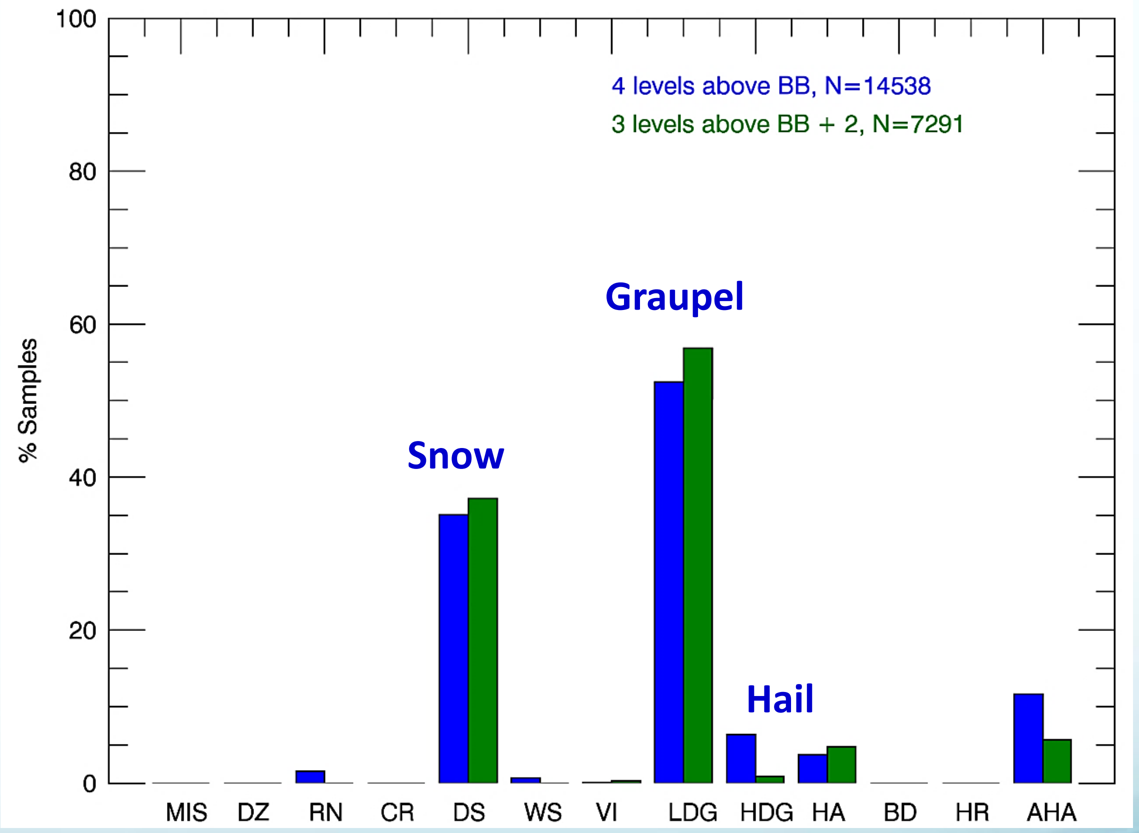
Isolating Convective D_m Behavior Relative to the Ice Process

When $D_m > 2.5$ More rimed ice (graupel/hail) aloft in convection

$1.0 < D_m < 2.5$



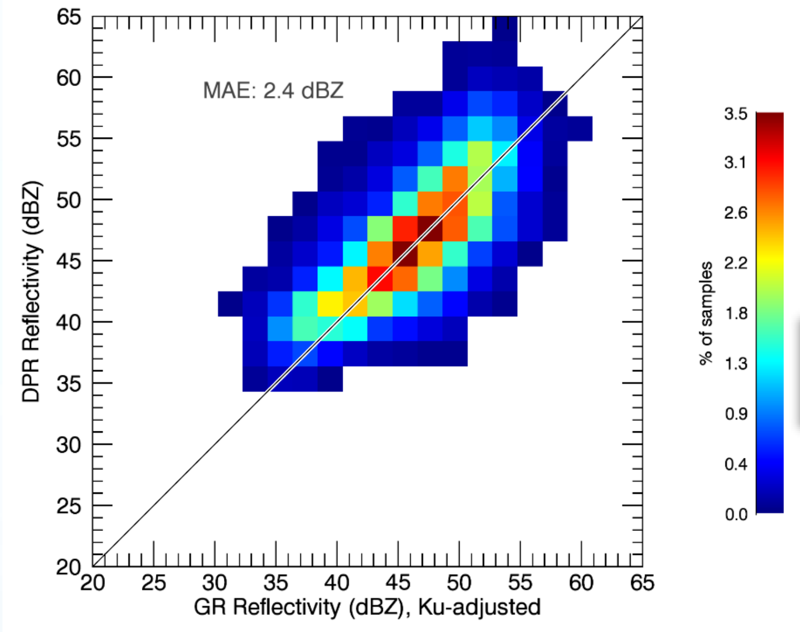
$D_m > 2.5$ mm



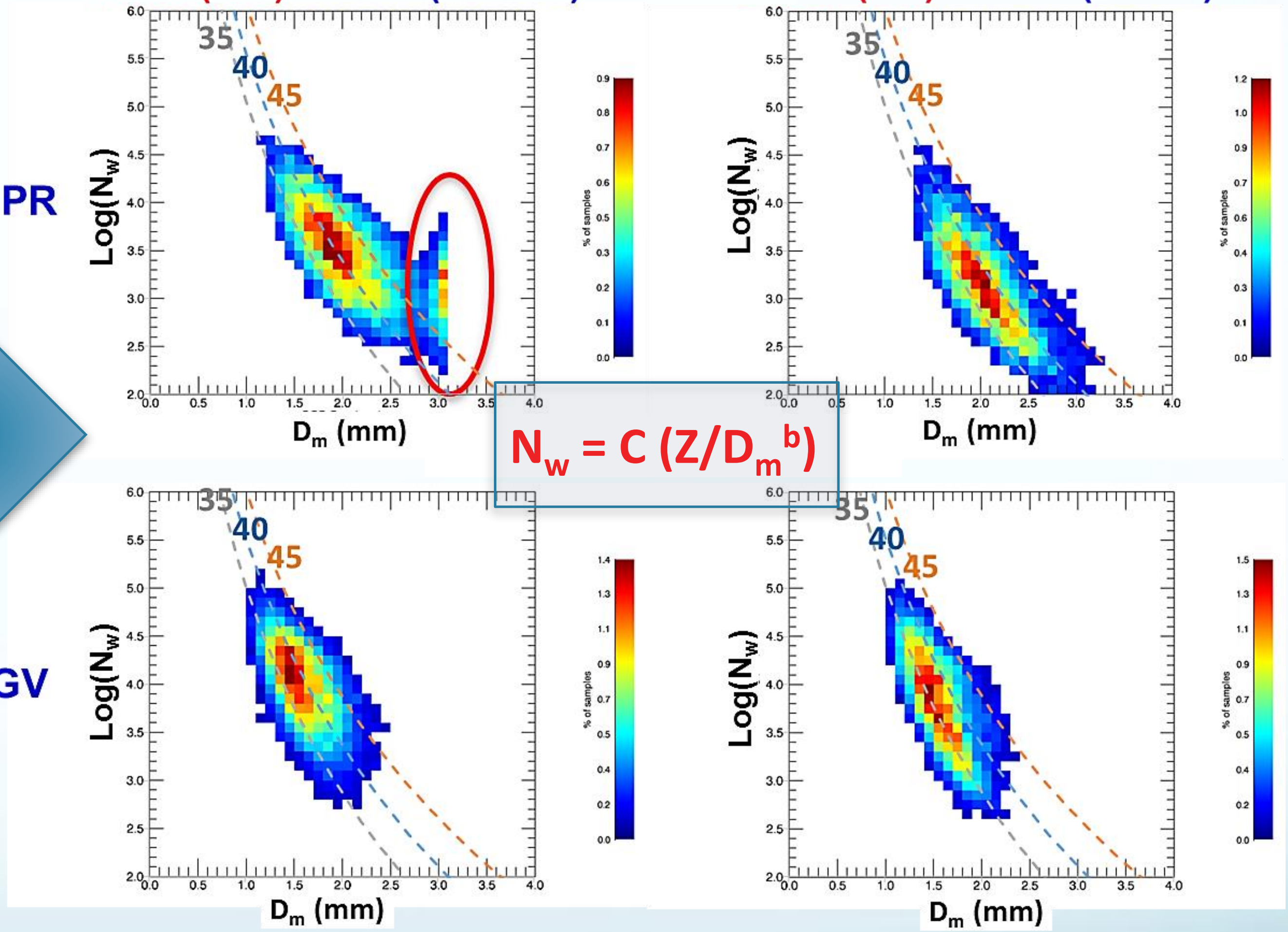
Also….PDFs of Z (not shown) indicate "large D_m" pixels have significantly larger Z both above and below the melting level.

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

GV Z vs. 2AKu Z (D_m > 2.5 mm)



2AKu, Z GV and 2AKu PR are very similar



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

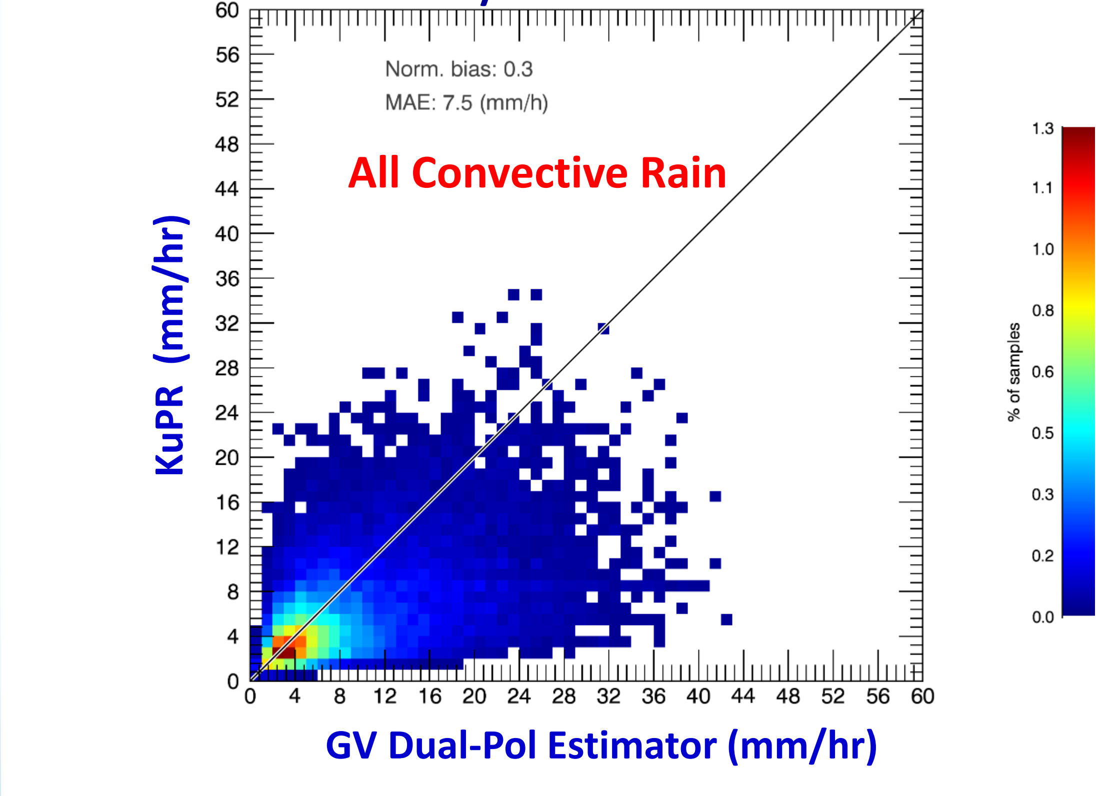
- DPR D_m bias implies lower N_w vs GV along Z-isopleths; bias is obvious but functional behavior similar (physics)

Impacts of Increasingly Positive D_m Bias in Convective Rain

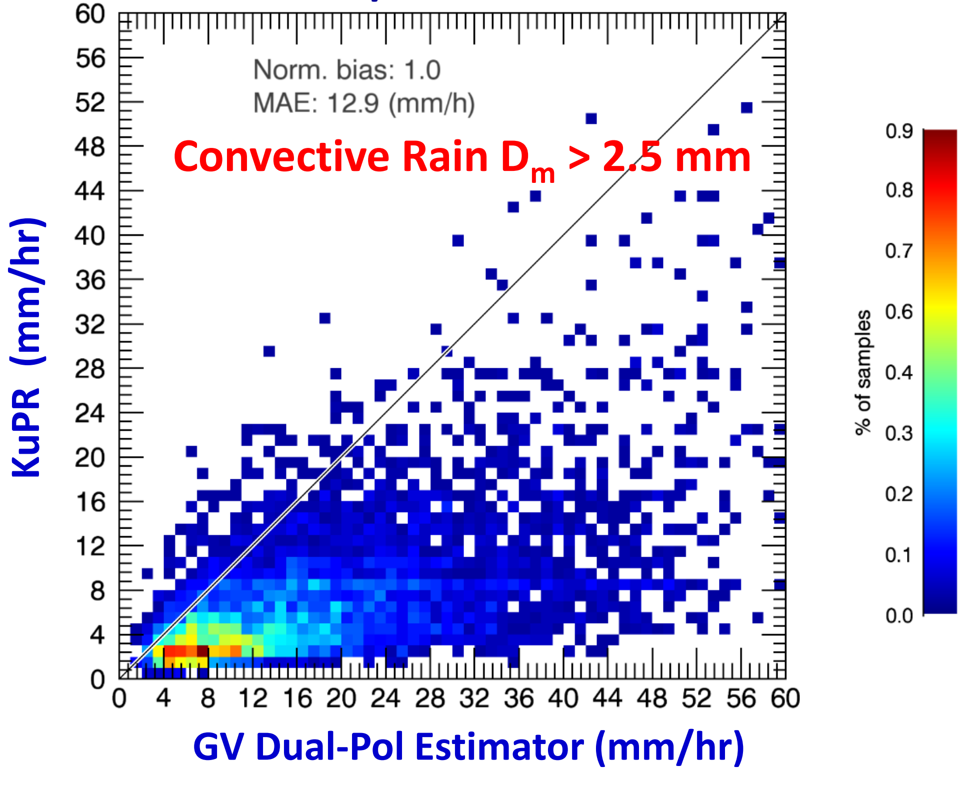
Marked low bias against GV rain rates when DPR-Identified large drop regimes occur

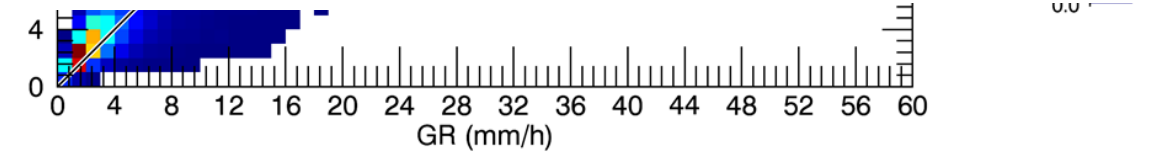
Performance reasonable from L1 science requirements standpoint

KuPR/DPR-NS Outer



KuPR/DPR-NS Outer



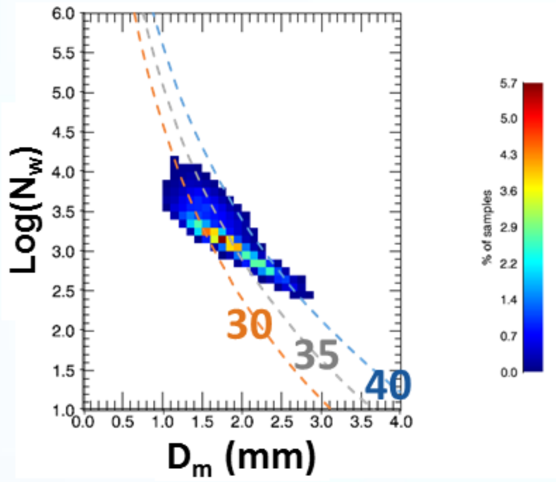


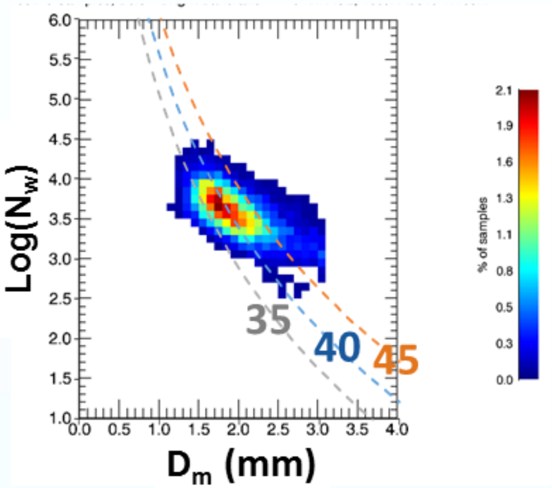
Combined Algorithm: MS Swath with GV (DSD, Rain, Z…)

- V5 N_w vs. $f(D_m, Z)$ trend (slope) is different from GV and DPR ….

Stratiform | **Convective**

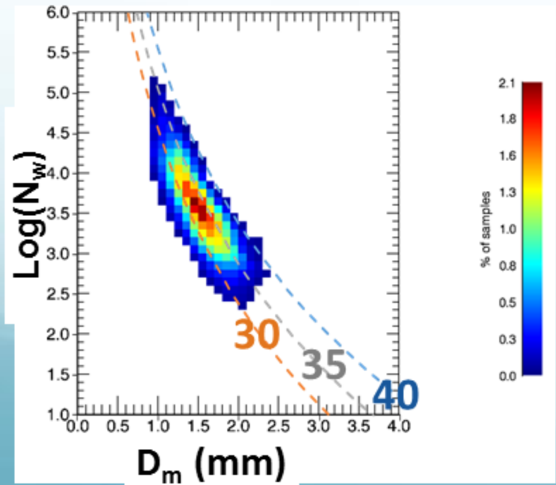
CMB

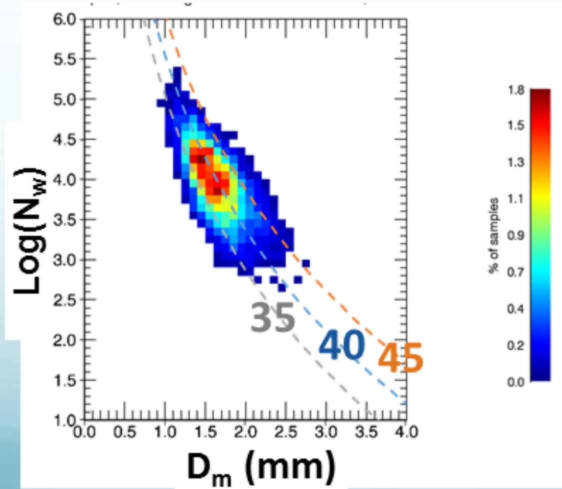




$N_w = C\,(Z/D_m^{\,b})$

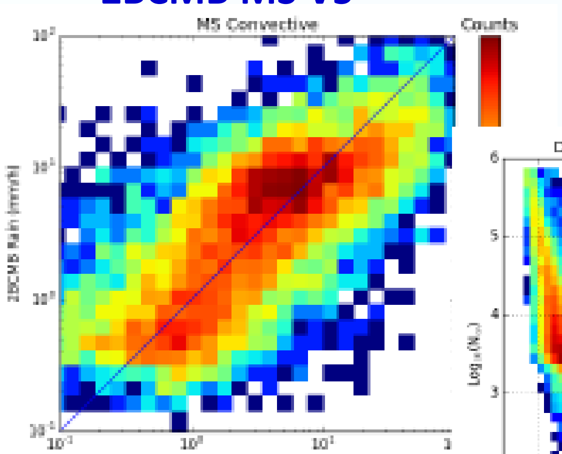
GV



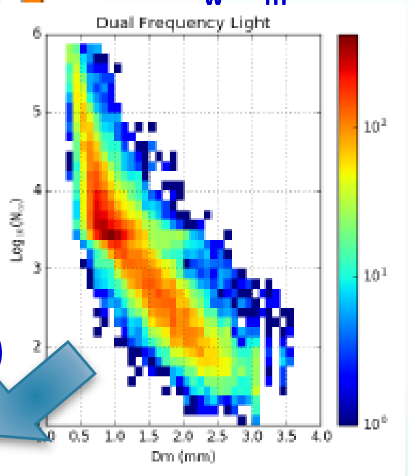


- New results (M. Grecu) using light N_w-Dm constraints (similar to GV)

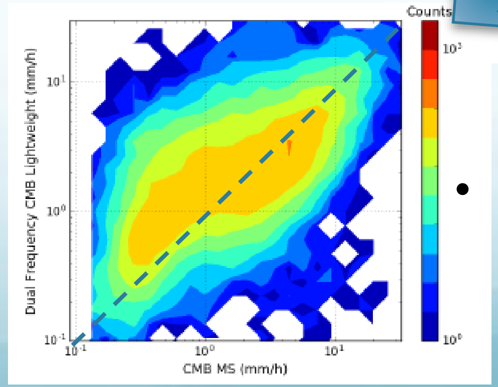
2BCMB MS V5



N_w-D_m



CMB MS (light constraint)



- Suggested improvement in “light constraint” retrievals.

Summary

Approach:

- **Polarimetric radar-based DSD retrievals (D_m, N_w) geo-matched and compared to GPM satellite footprints/swaths.**

Results:

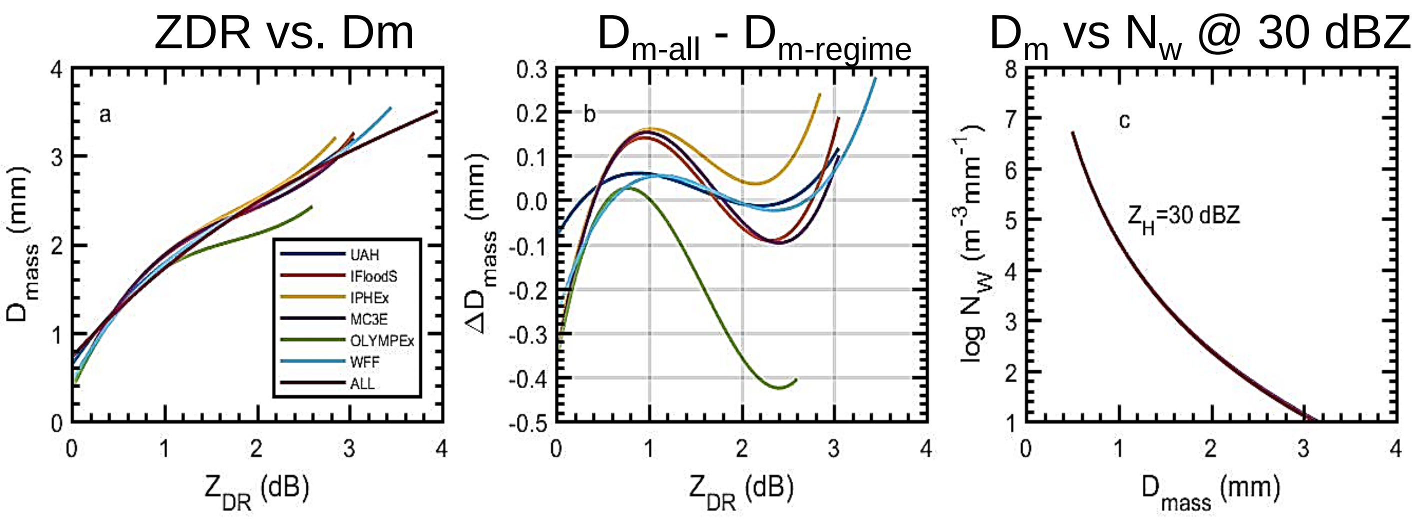
- **Level 1 requirement of D_m within +/- 0.5 mm is overall satisfied in V5 (V6-prelim version nearly identical).**
- **DPR: Sensitivity to rain type-**
  - **KuPR, DPR *convective* D_m positive biases relative to GV- "large D_m" bias but similar physical behavior in N_w-D_m space**
  - **Large D_m-bias associated with convection having more frequent and deeper graupel/dense ice HID categories**
  - **Big D_m (low N_w) bias associated with a *marked convective rainfall under-estimate***
- **Combined-Algorithm: N_w vs. D_m behavior is different than DPR or GV in V5; testing with improved DSD constraints suggests reduction in rain rate bias.**

Moving ahead:

- **For future versions isolate *details* of DSD behavior as a function of GPM algorithm assumptions (e.g., attenuation correction, R-D_m, beam filling impacts)**
- **Continue to evaluate and refine GV approach**

Backup

Approach: Check Aggregate against Individual Regimes



Application of the "ALL" relationship to certain regimes (e.g., OLYMPEX) with less frequently sampled large ZDR (e.g., OLYMPEX) introduces more uncertainty in D_m;

N_w behavior much more stable.

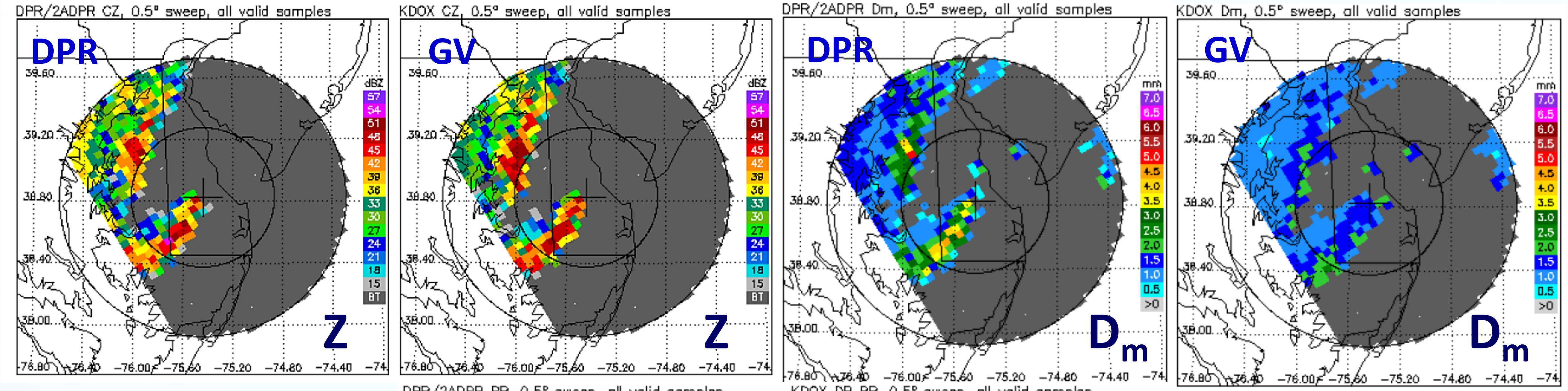
Regime Sub-sample comparisons to NPOL

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: Regime D_m, N_w fits tested using NPOL observations and field 2DVDs
- Bias behavior is good.

Tokay et al. 2017 (in preparation)

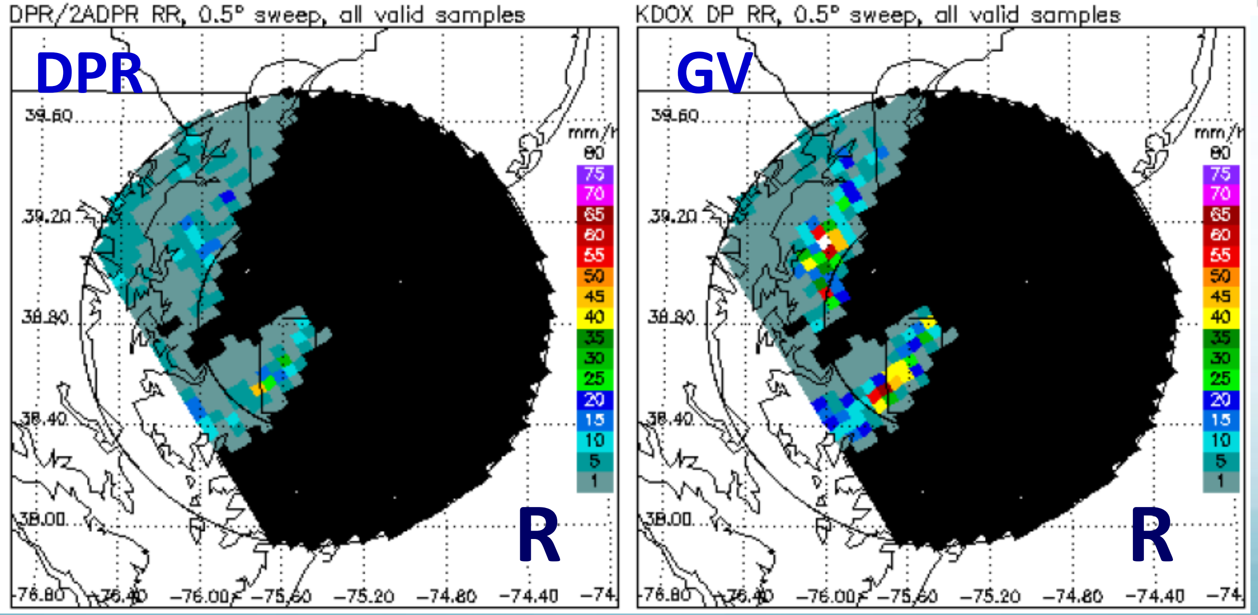
Explore DPR Convective: A "Case" Example



Z- similar

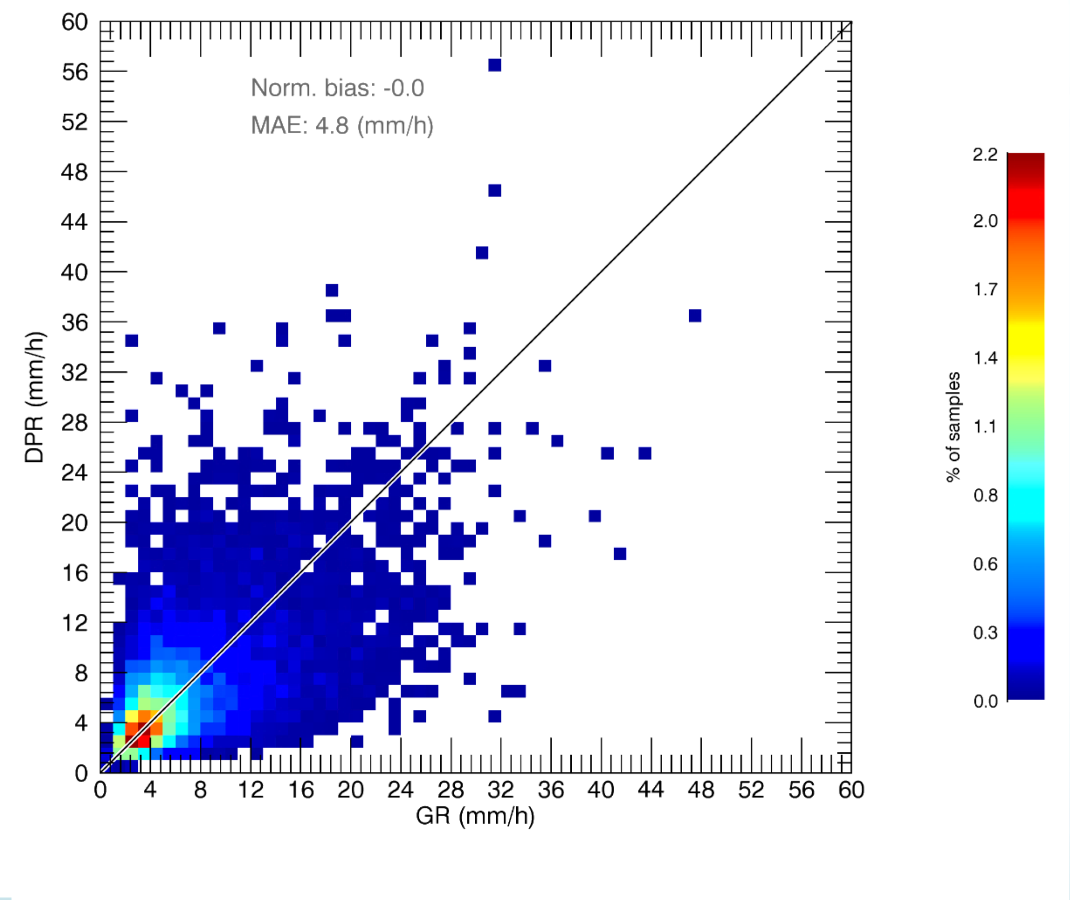
DPR D_m - larger

DPR R - smaller (in convective cores)



DSD "Big D_m" Impact

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



Yes.

Intra-Footprint Variability of Large D_m–Pixels: Greater Below/Above the Melting Layer