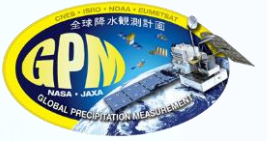
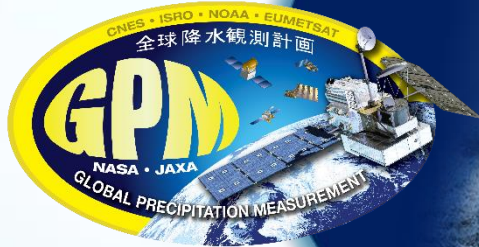




# A RADAR-BASED EVALUATION OF GPM RETRIEVALS OF THE RAIN DROP SIZE DISTRIBUTION



Walter A. Petersen, and Patrick N. Gatlin, Earth Science Branch, ST-11, NASA-MSFC  
David B. Wolff, NASA /GSFC-WFF, Ali Tokay, GSFC/UMBC, M. Grecu, GSFC/Morgan State U.

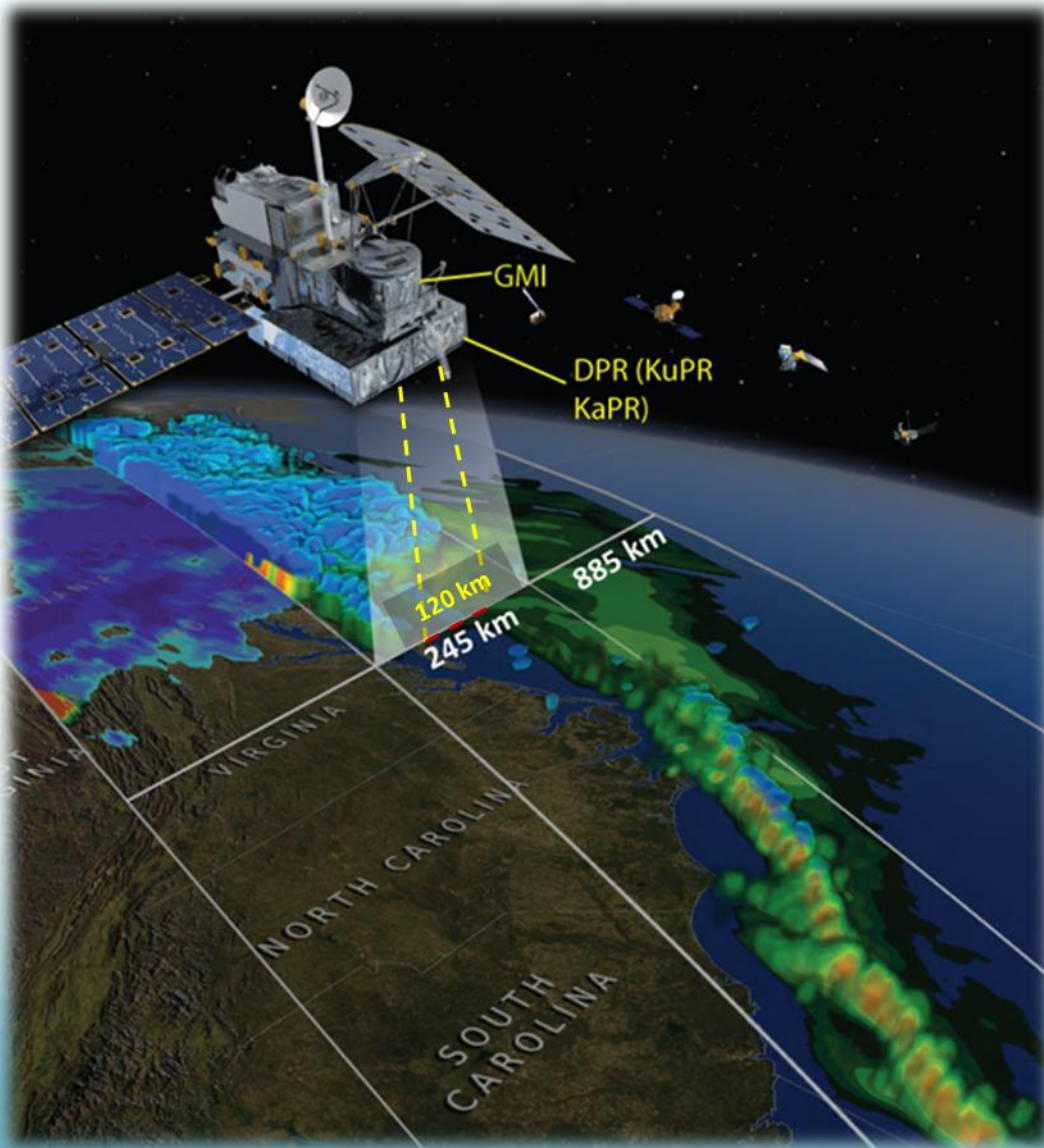


## Outline

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

**Acknowledgements:** L. P. D'Aderrio (U. Ferrara), T. Berendes (MSFC/UAH), D. Marks (WFF/SSAI), J. Pippitt (GSFC/SSAI), M. Wingo (MSFC/UAH)

**Research Support:** NASA Precipitation Measurement Mission Science Team, Global Precipitation Measurement mission

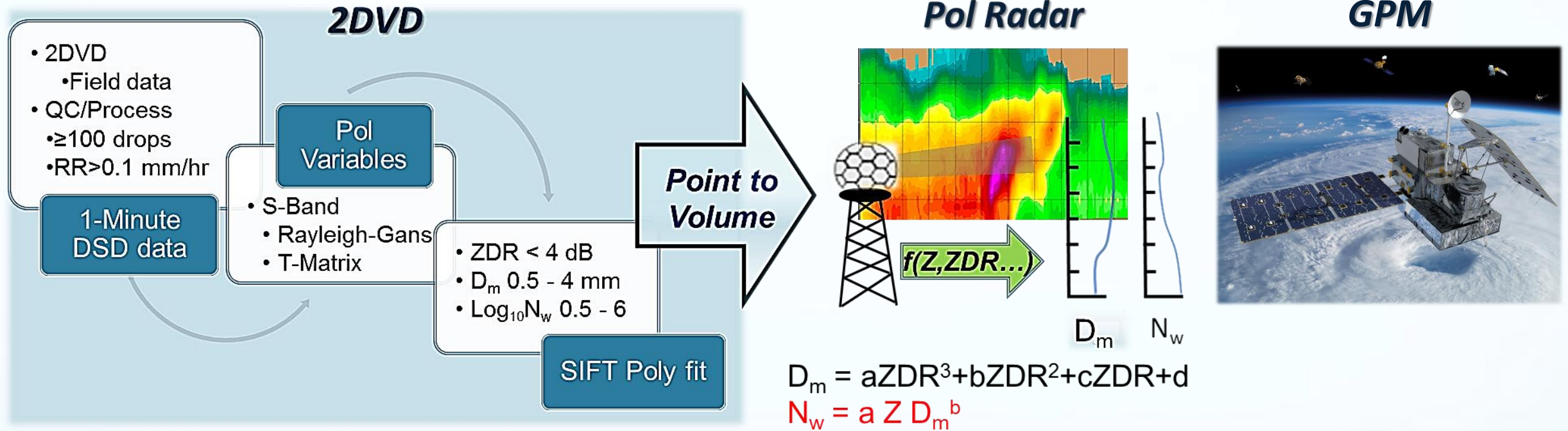
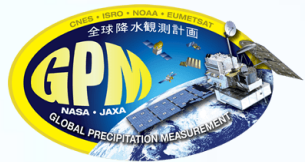


## GPM “Core” L1 Science Requirements

- DPR: *quantify rain rates between 0.22 and 110 mm hr<sup>-1</sup> and demonstrate the detection of snowfall at an effective resolution of 5 km.*
- GMI: *quantify rain rates between 0.22 and 60 mm hr<sup>-1</sup> 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<sup>-1</sup> and < 25% at 10 mm hr<sup>-1</sup>, relative to GV
- **Core observatory estimation of the Drop Size Distribution (DSD)  $D_m$  to within +/- 0.5 mm. [note- no  $N_w$  requirement]**



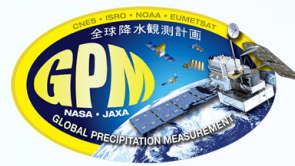
# Approach: 2DVD to Radar, Radar to Satellite



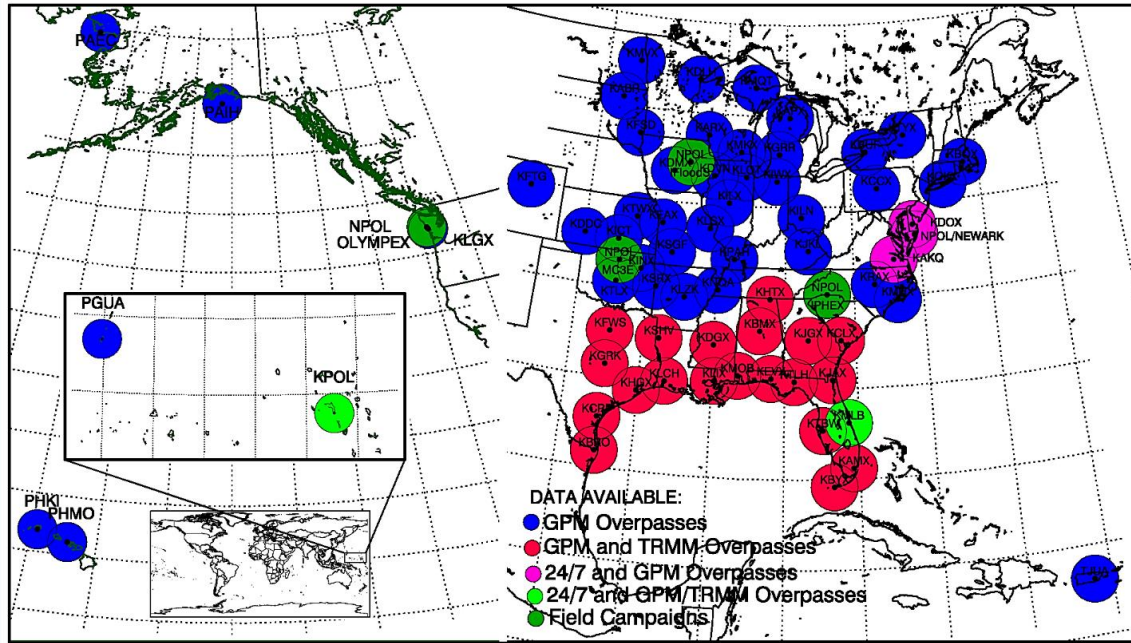
- Empirical models developed for NASA field campaign "regimes" (Oklahoma, Iowa, Alabama, Mid-Atlantic Coastal, Washington Coast, Appalachians/Piedmont....)
- Aggregated "DSD fit" to make "**ALL-regimes**" for U.S. continental-scale statistical verification (> 200,000 minutes used)
  - "**ALL**" DSD model-fit relative errors: **BIAS < 10%, MAE < 15%**



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



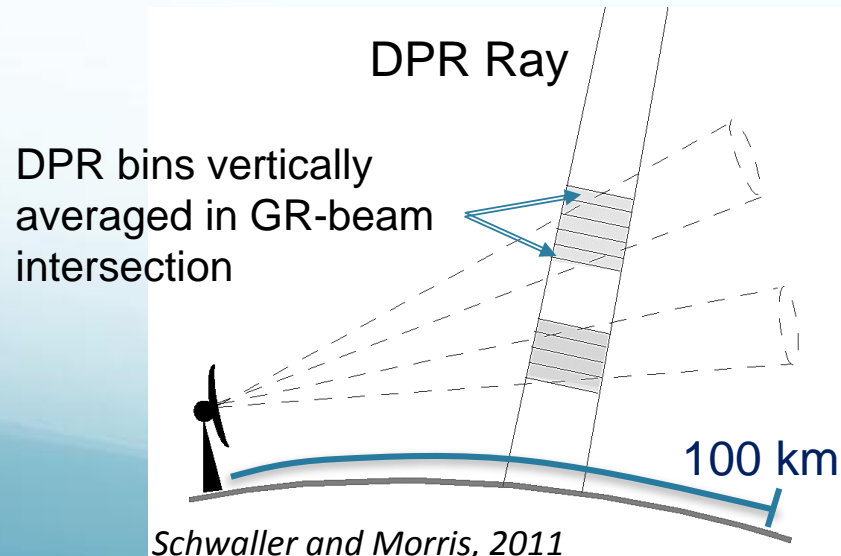
GPM-GV Radar Sites



## 88Ds, NPOL, KWAJ

Dual-pol quality-controlled moments and diagnostics (DSD, rain rate, HID etc.) computed from ~70 network radars

## 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...)

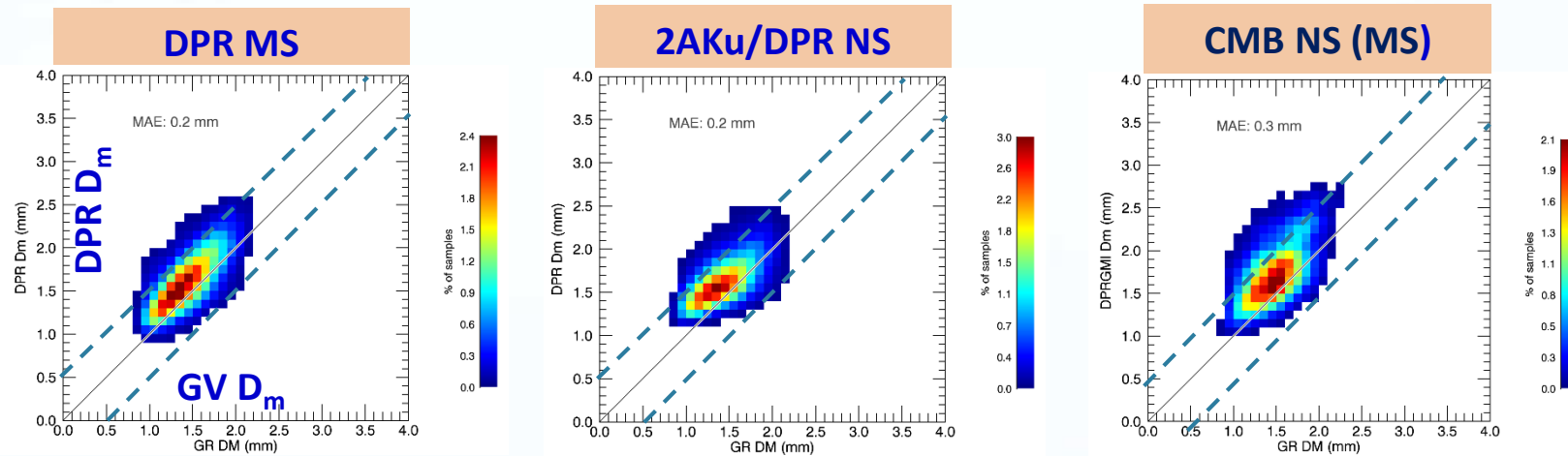


# L1 Requirement DSD: Continental Scale VN-GPM Comparisons

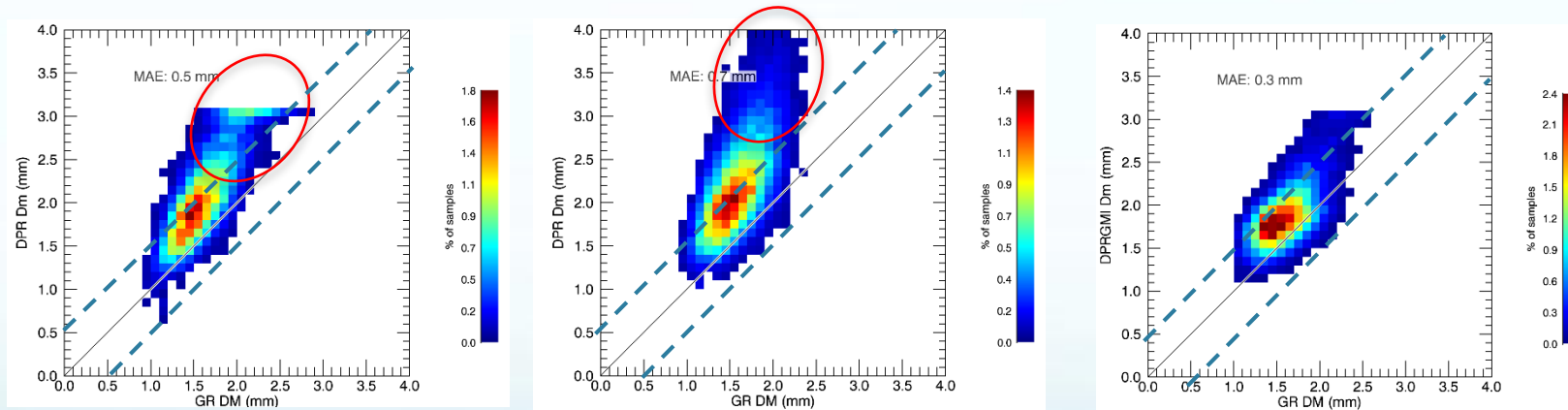


DPR, 2AKu, CMB **V5  $D_m$**  vs. **GV Radar  $D_m$**

Stratiform



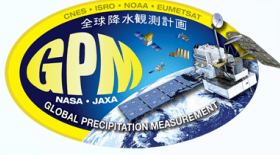
Convective



- 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)

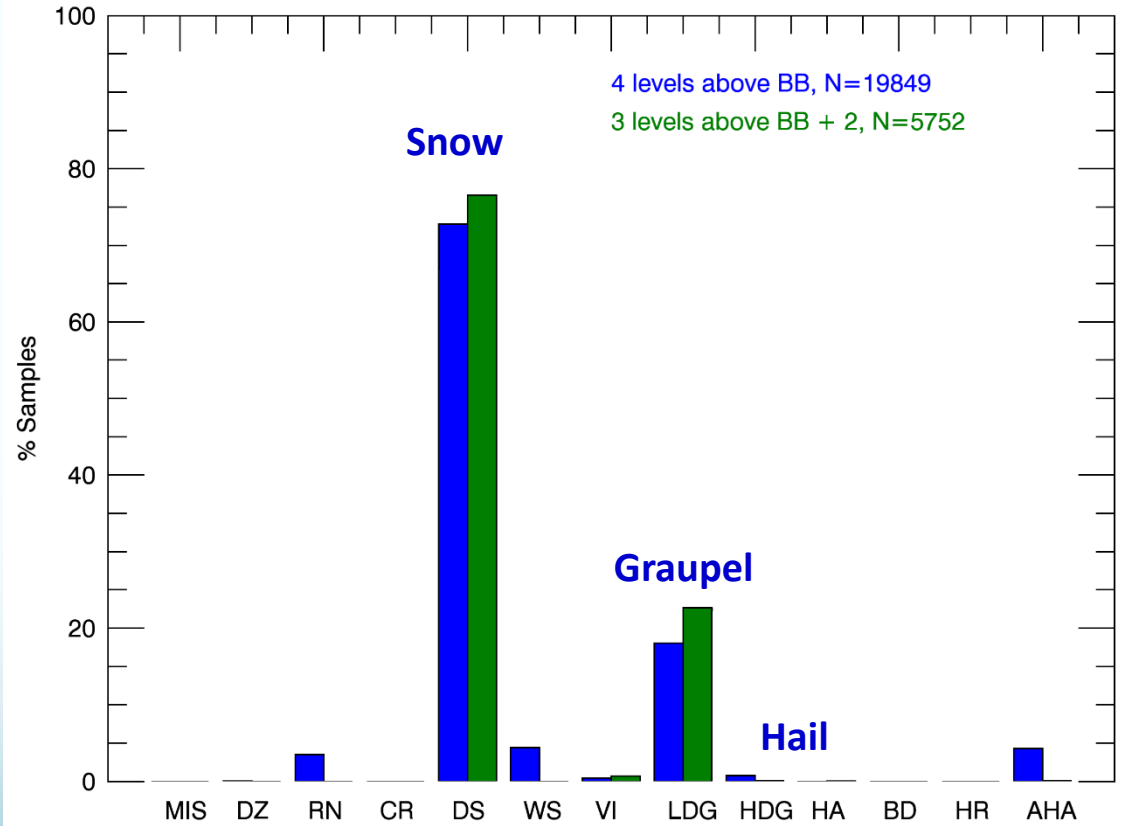


# Isolating Convective $D_m$ Behavior Relative to the Ice Process

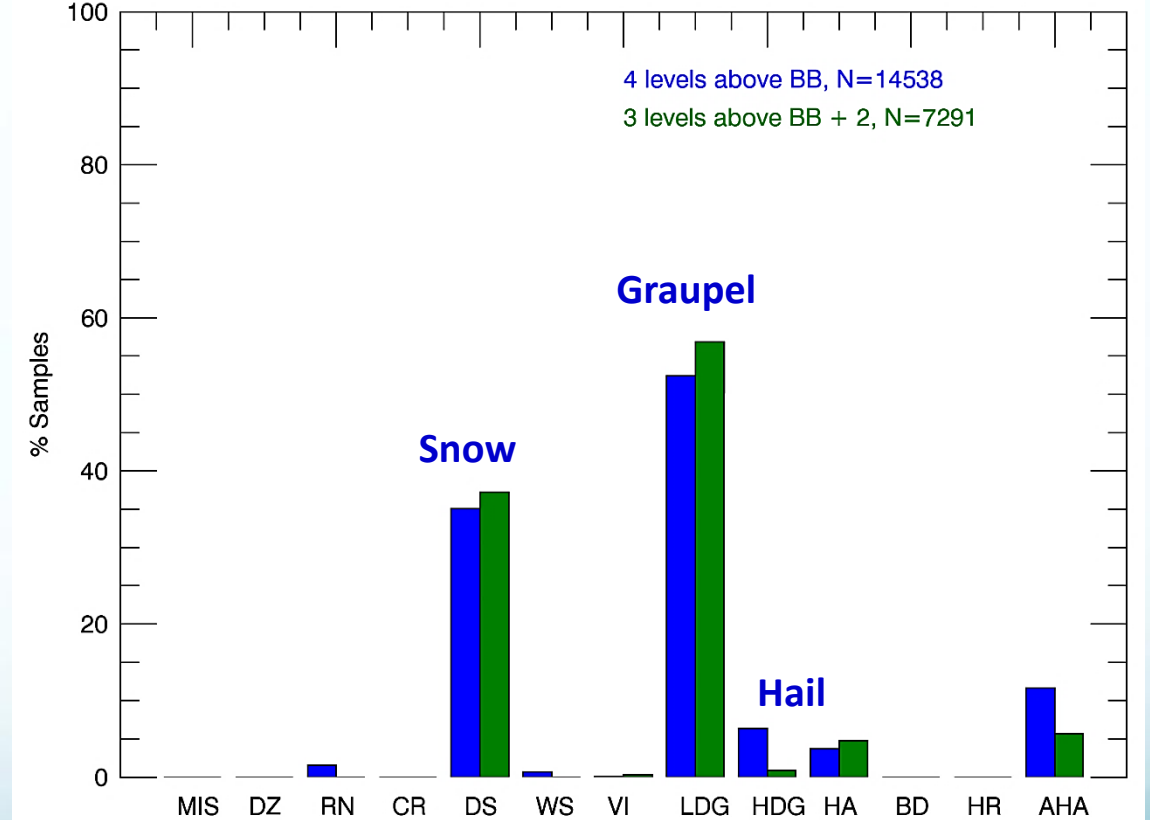


When  $D_m > 2.5$  More rimed ice (graupel/hail) aloft in convection

$1.0 < D_m < 2.5$



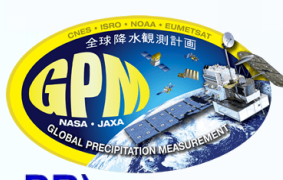
$D_m > 2.5$  mm



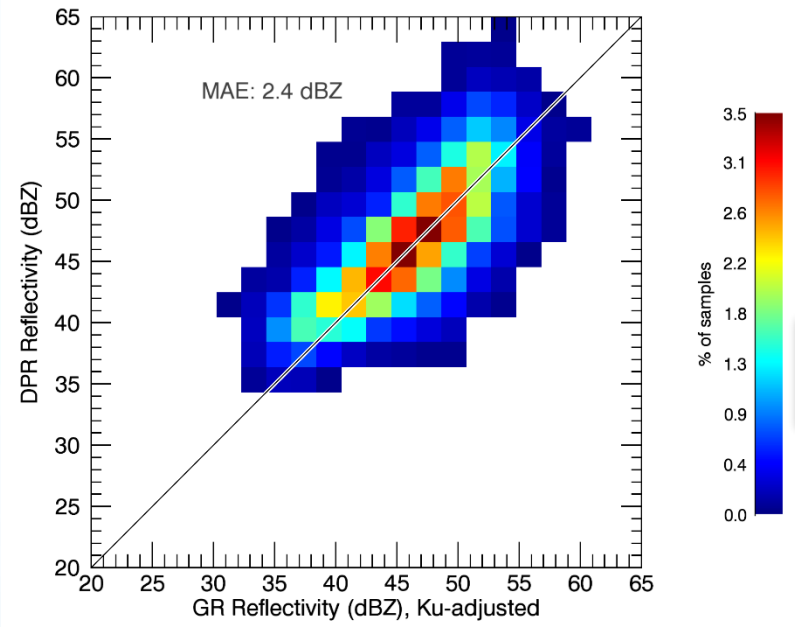
Also....PDFs of Z (not shown) indicate “large  $D_m$ ” pixels have significantly larger Z both above and below the melting level.



# 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)

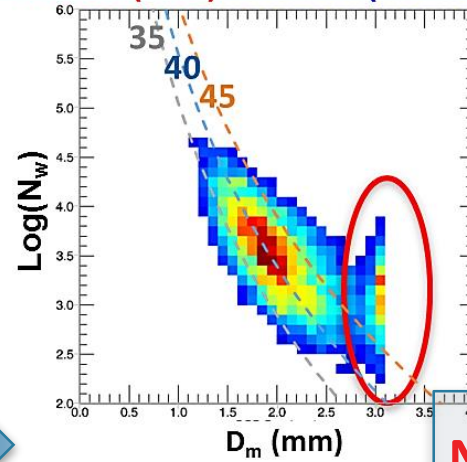


2AKu, Z GV and 2AKu PR are very similar

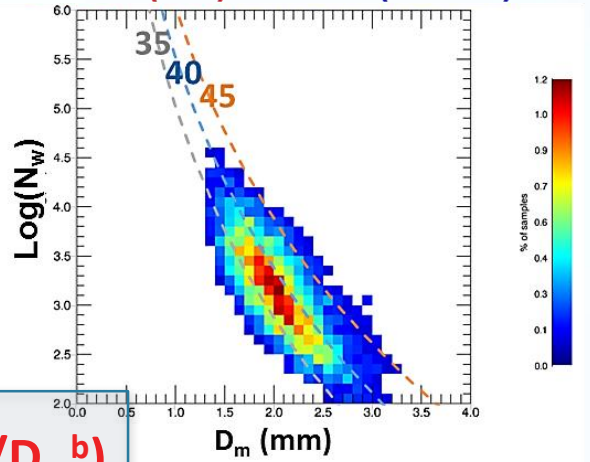
DPR

GV

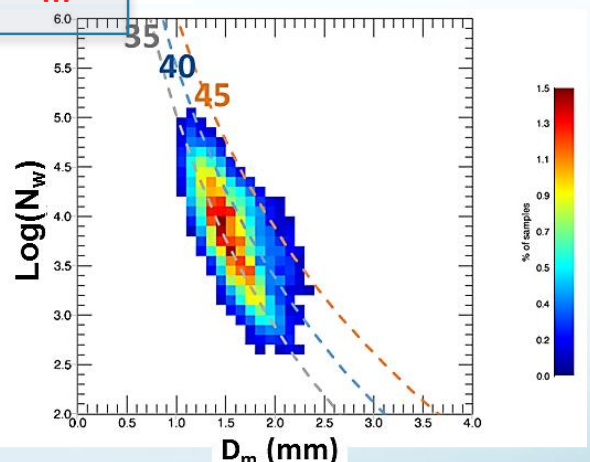
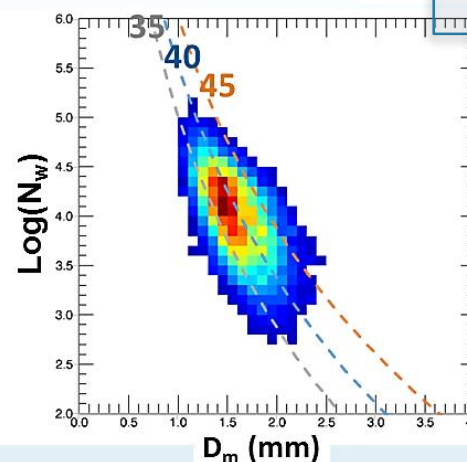
### Inner (MS) Swath (Ka+Ku)



### Outer (NS) Swath (KuPR)



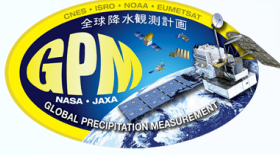
$$N_w = C (Z/D_m^b)$$



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



# Impacts of Increasingly Positive $D_m$ Bias in Convective Rain



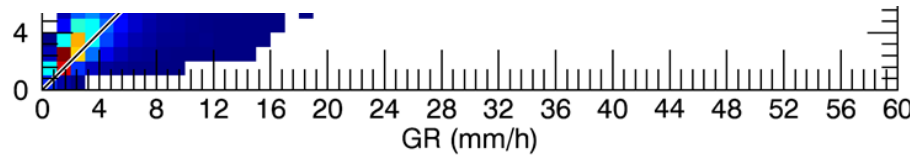
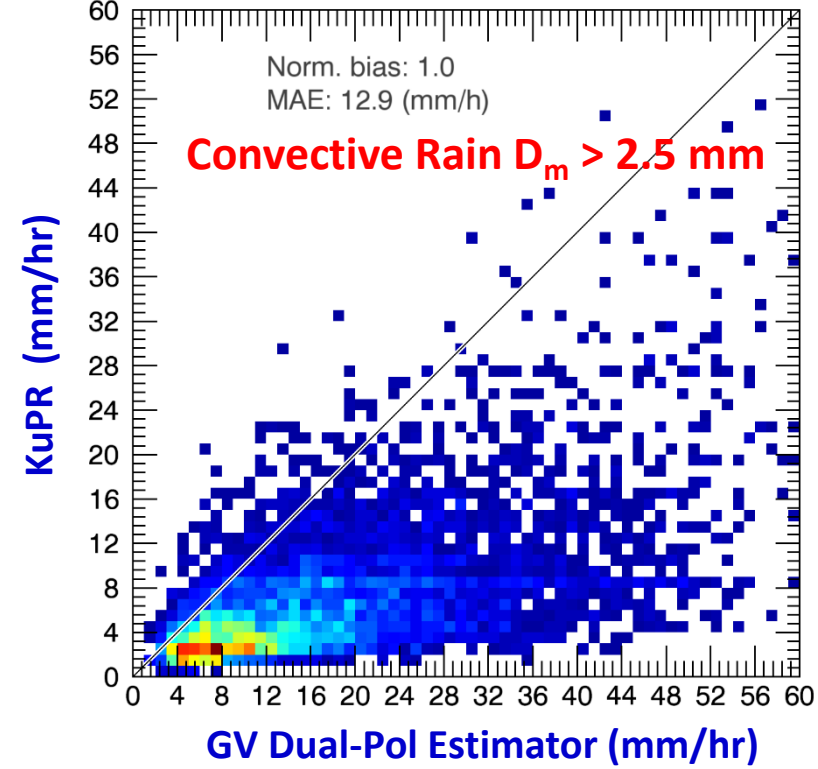
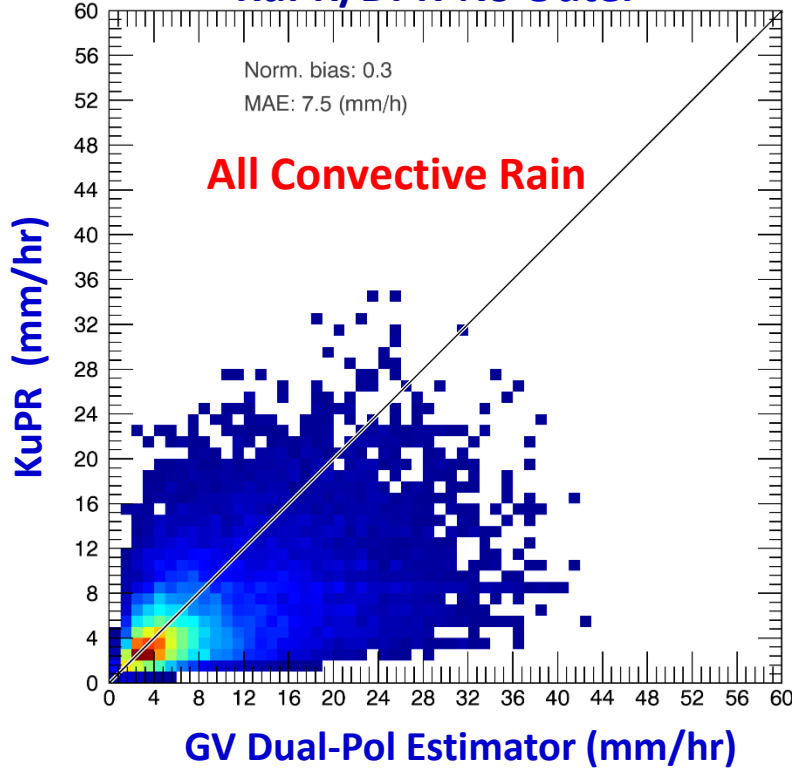
Marked low bias against GV rain rates when DPR-Identified large drop regimes occur

Performance reasonable from L1 science

KuPR/DPR-NS Outer

requirements standpoint

KuPR/DPR-NS Outer





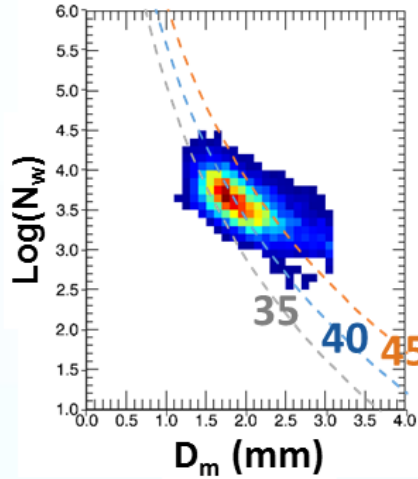
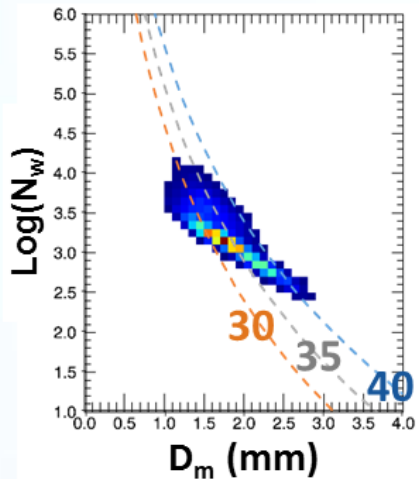
# Combined Algorithm: MS Swath with GV (DSD, Rain, Z...)



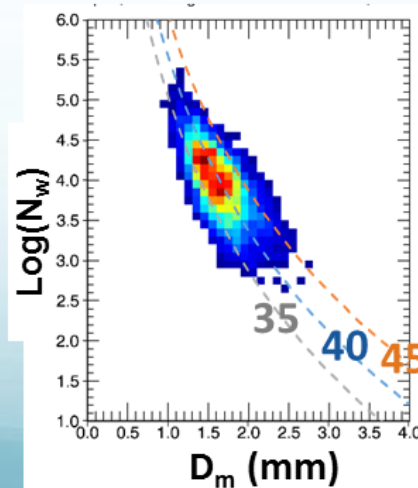
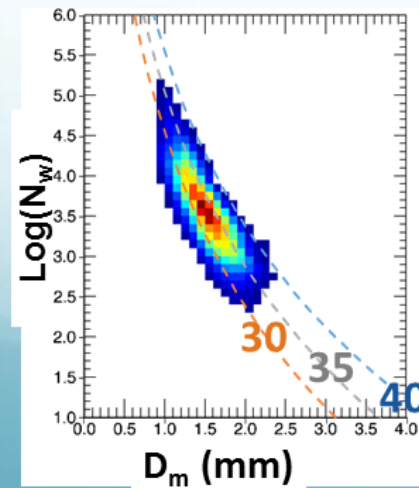
- V5  $N_w$  vs.  $f(D_m, Z)$  trend (slope) is different from GV and DPR ...

Stratiform

Convective

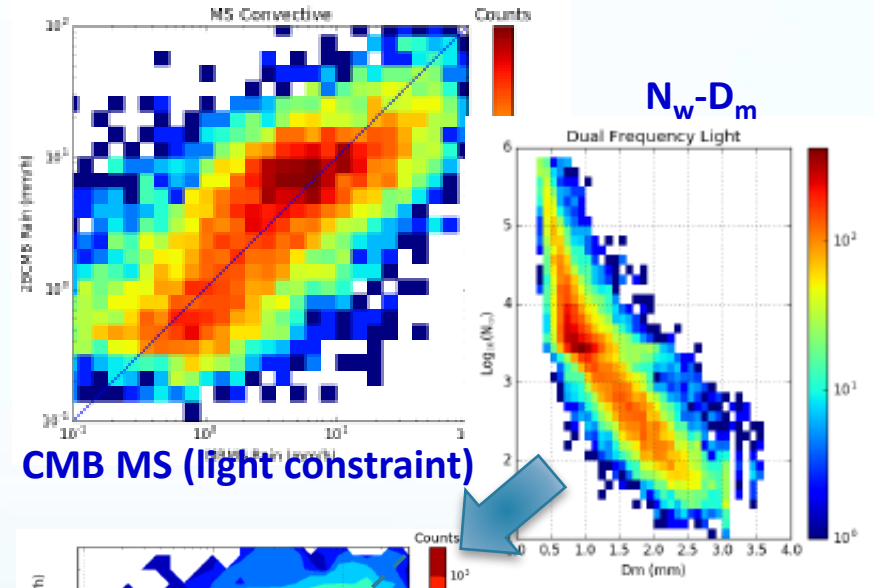


$$N_w = C (Z/D_m)^b$$

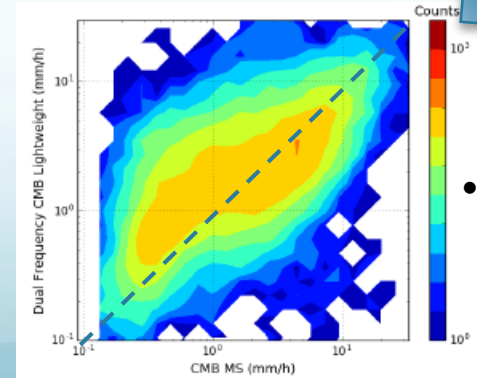


- New results (M. Greco) using light  $N_w$ - $D_m$  constraints (similar to GV)

2BCMB MS V5



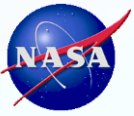
CMB MS (light constraint)



- Suggested improvement in "light constraint" retrievals.

CMB

GV



# 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.

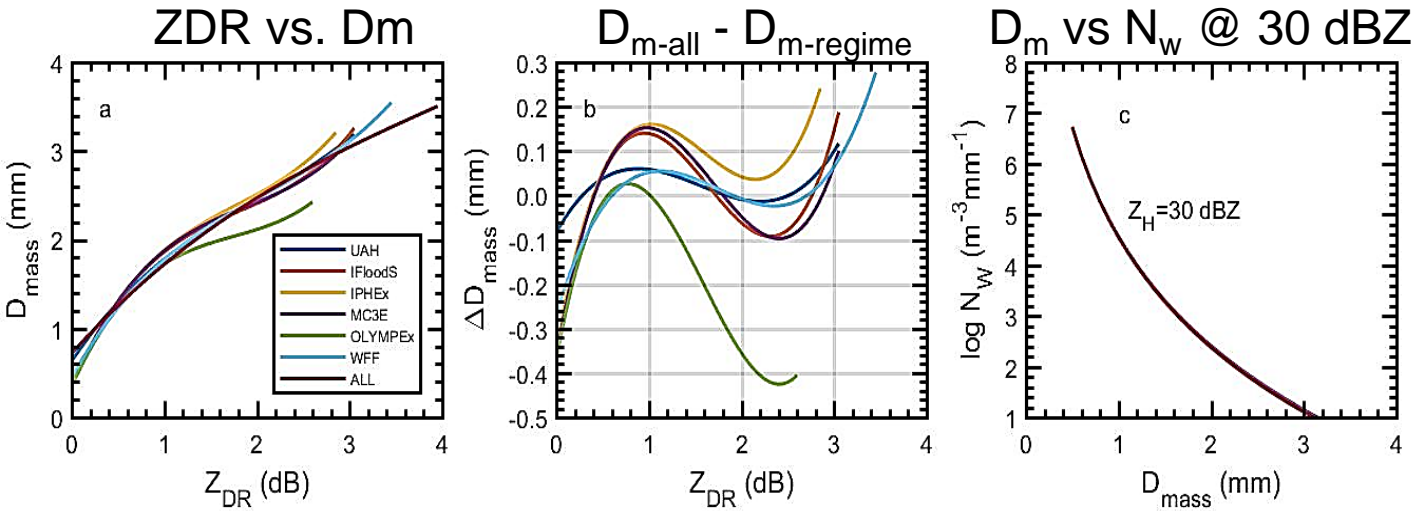
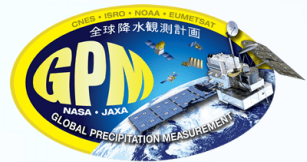
## Moving ahead:

- 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



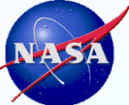
Application of the "ALL" relationship to certain regimes (e.g., OLYMPEX) with less frequently sampled large ZDR (e.g., OLYMPEX) introduces more uncertainty in  $D_m$ ;

$N_w$  behavior much more stable.

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

Regime Sub-sample comparisons to NPOL

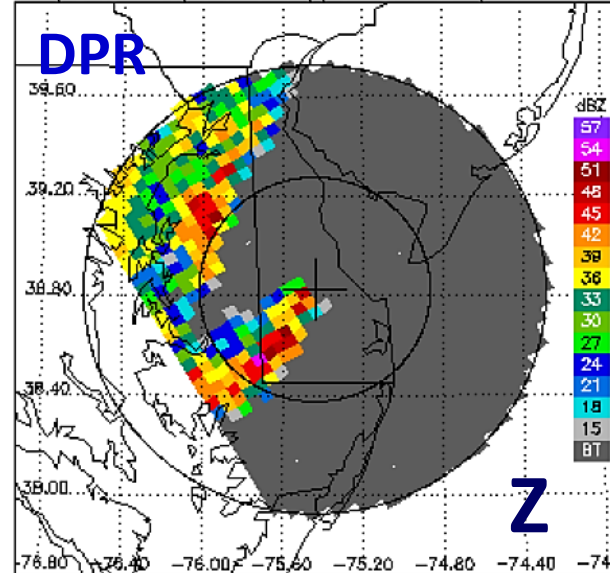
Field Campaign	Bias	Absolute Bias	Samples
<b><math>D_m</math></b>			
IFloods	0.00	0.42	6,610
IPHEX	0.07	0.34	1,058
OLYMPEX	0.03	0.34	1,008
<b>LOG10[<math>N_w</math>]</b>			
IFloods	0.04	0.90	6,610
IPHEX	-0.12	0.89	1,058
OLYMPEX	0.21	0.89	1,008



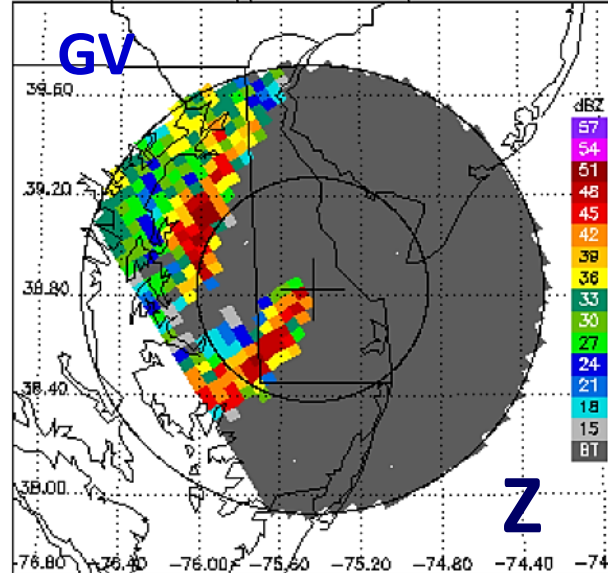
# Explore DPR Convective: A "Case" Example



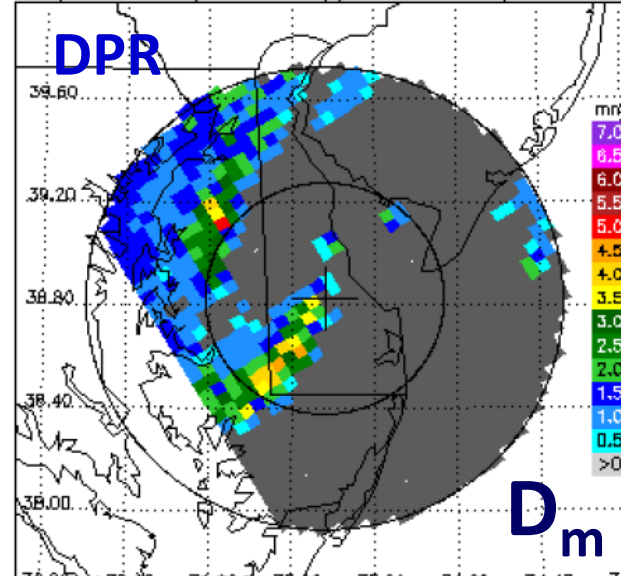
DPR/2ADPR CZ, 0.5° sweep, all valid samples



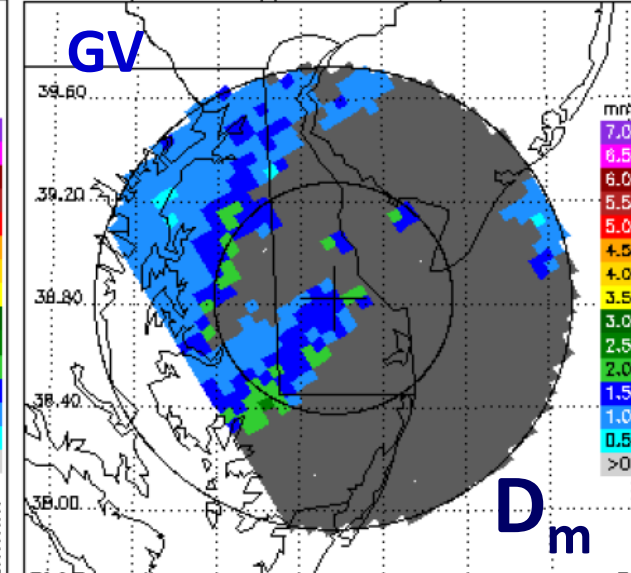
KDOX CZ, 0.5° sweep, all valid samples



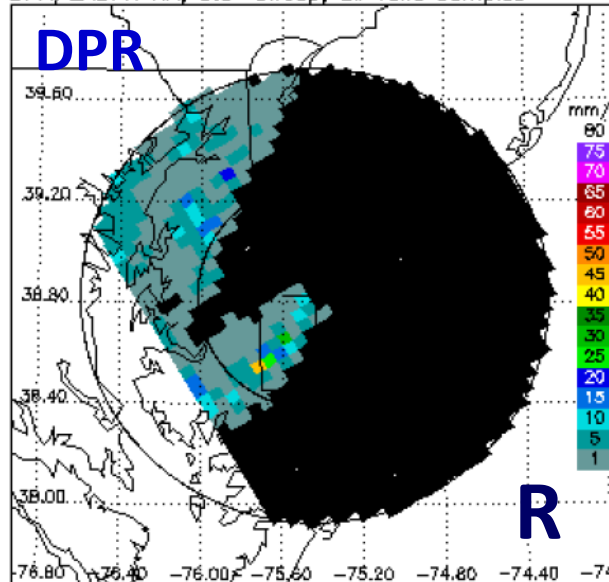
DPR/2ADPR Dm, 0.5° sweep, all valid samples



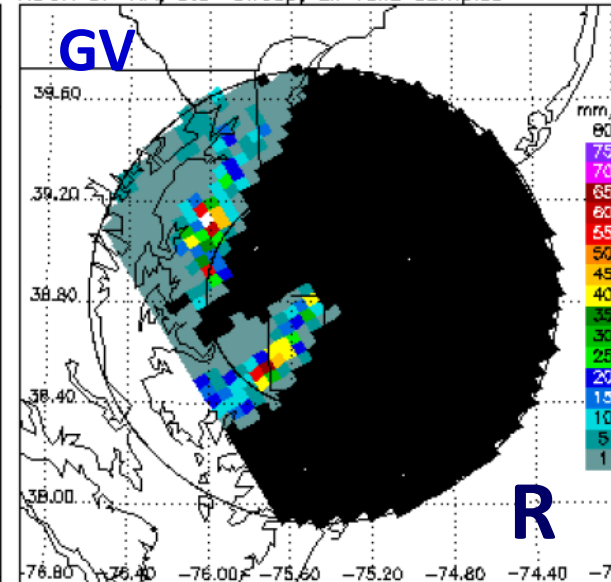
KDOX Dm, 0.5° sweep, all valid samples



DPR/2ADPR RR, 0.5° sweep, all valid samples



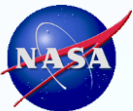
KDOX DP RR, 0.5° sweep, all valid samples



**Z- similar**

**DPR D<sub>m</sub> - larger**

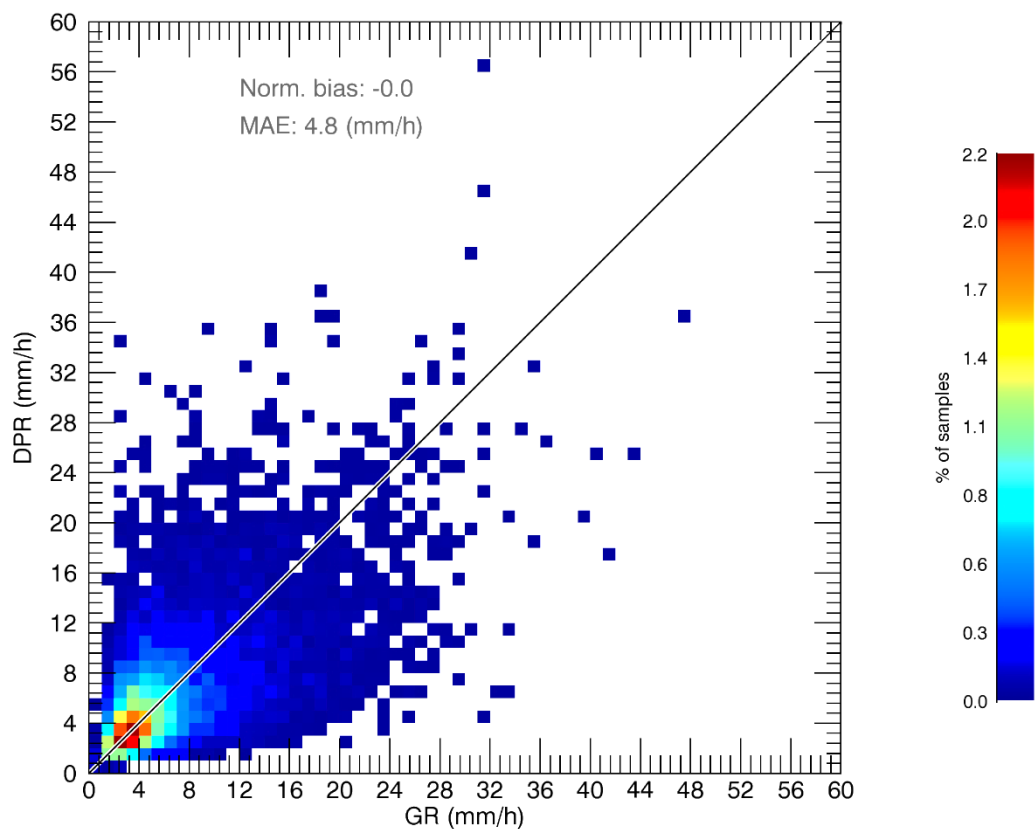
**DPR R - smaller (in convective cores)**



# DSD "Big D<sub>m</sub>" Impact



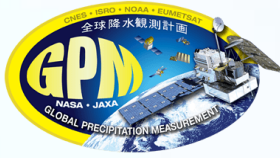
Tail of "big-D<sub>m</sub>" data points makes up ~12% of the convective sample.....  
Worth fixing/examining more?



Yes.

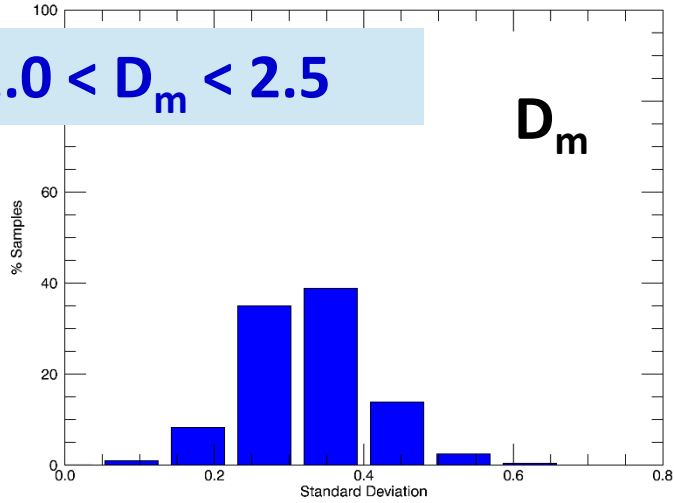


# Intra-Footprint Variability of Large $D_m$ -Pixels: Greater Below/Above the Melting Layer



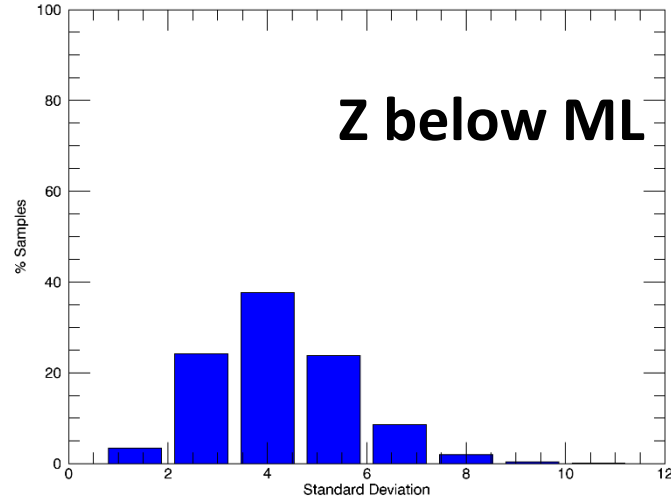
2AKu/NS V05A GR Dm Std Dev Histogram, N=24851  
Convective Samples, Below Bright Band and  $\leq 3$  km AGL, 100% Above Thresh DPR Dm GE 1.0 LE 2.5

$1.0 < D_m < 2.5$



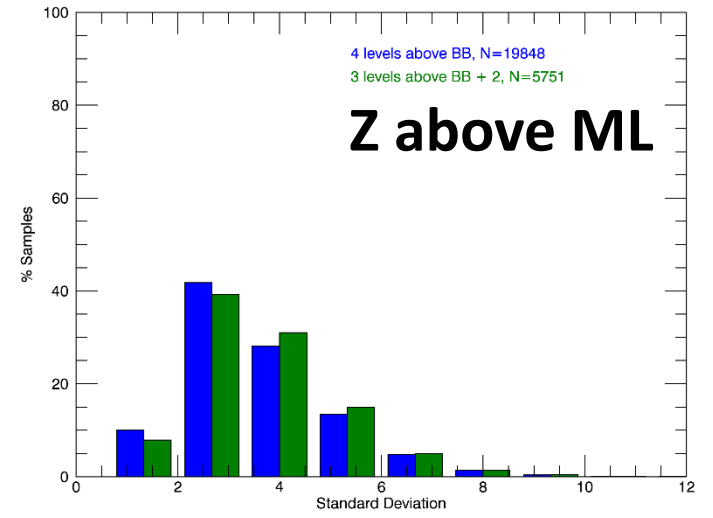
GR Z Std Dev Histogram 2AKu/NS for DPR V05A, N=24853  
Convective Samples, Below Bright Band and  $\leq 3$  km AGL, 100% Above Thresh DPR Dm GE 1.0 LI

**Z below ML**



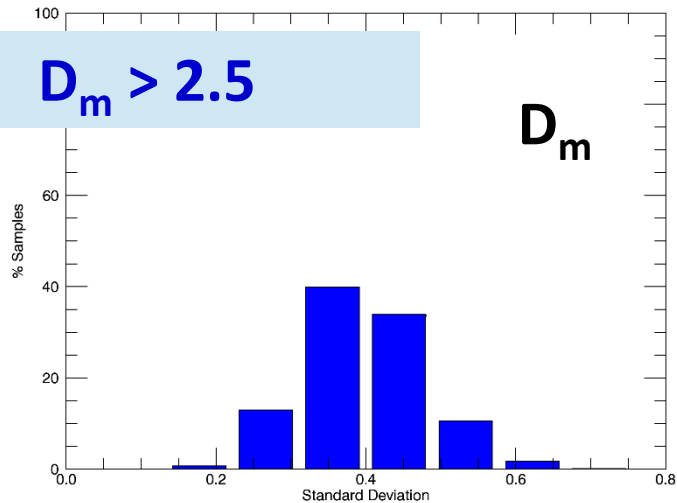
GR Z Std Dev Histogram 2AKu/NS for DPR V05A  
convective above BB up to four 1.5km layers, 100% Above Thresh DPR Dm GE 1.0 LE 2.5

**Z above ML**



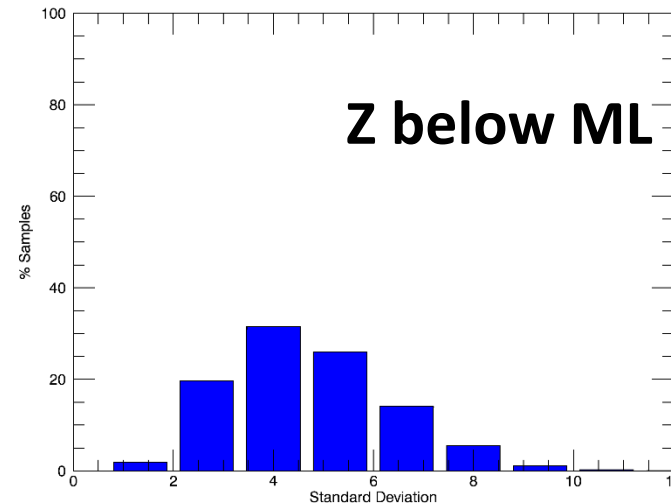
2AKu/NS V05A GR Dm Std Dev Histogram, N=11474  
Convective Samples, Below Bright Band and  $\leq 3$  km AGL, 100% Above Thresh DPR Dm GE 2.7

$D_m > 2.5$



GR Z Std Dev Histogram 2AKu/NS for DPR V05A, N=11474  
Convective Samples, Below Bright Band and  $\leq 3$  km AGL, 100% Above Thresh DPR Dm GE 2.

**Z below ML**



GR Z Std Dev Histogram 2AKu/NS for DPR V05A  
convective above BB up to four 1.5km layers, 100% Above Thresh DPR Dm GE 2.7

**Z above ML**

