Dataset Analysis to Support Verification of GPM Science Requirements

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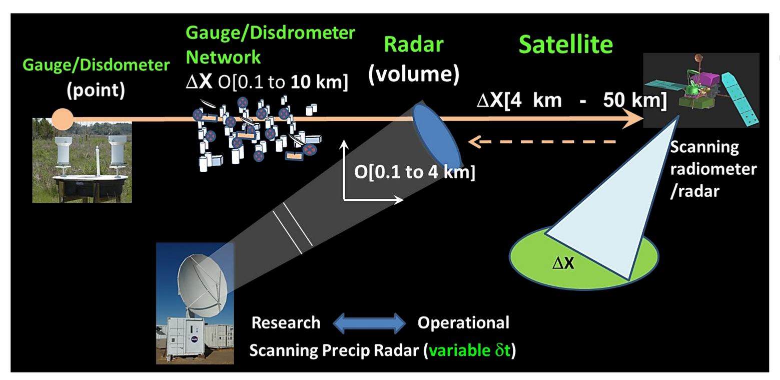
1. Objective: Validation of GPM Core Science Requirements

- DPR (GMI): quantify rain rates of 0.22 (0.20) to 110 (60) mm hr^{-1} and demonstrate detection of snowfall at effective resolution(s) of 5 (15) km.
- GPM Core observatory radar estimation of D_m to within +/- 0.5 mm
- Instantaneous rain rate estimation at 50 km resolution, bias and random error < 50% at 1 mm hr^{-1} and < 25% at 10 mm hr^{-1}, relative to GV

2. Approaches



Overarching concept: GV Radars and PMM science bridge point to FOV/swath

Gauges, disdrometers reference ground-based multi-parameter radar networks

Figure 1. Radars as a bridge between gauge and disdrometer "point" scales

Rain Rate (RR)

- CONUS: Orbit coincident gauge-adjusted radar RRs from GPM GV-specific Level-2 Multi-Radar Multi-Sensor (GV-MRMS), liquid only, "best" pixels

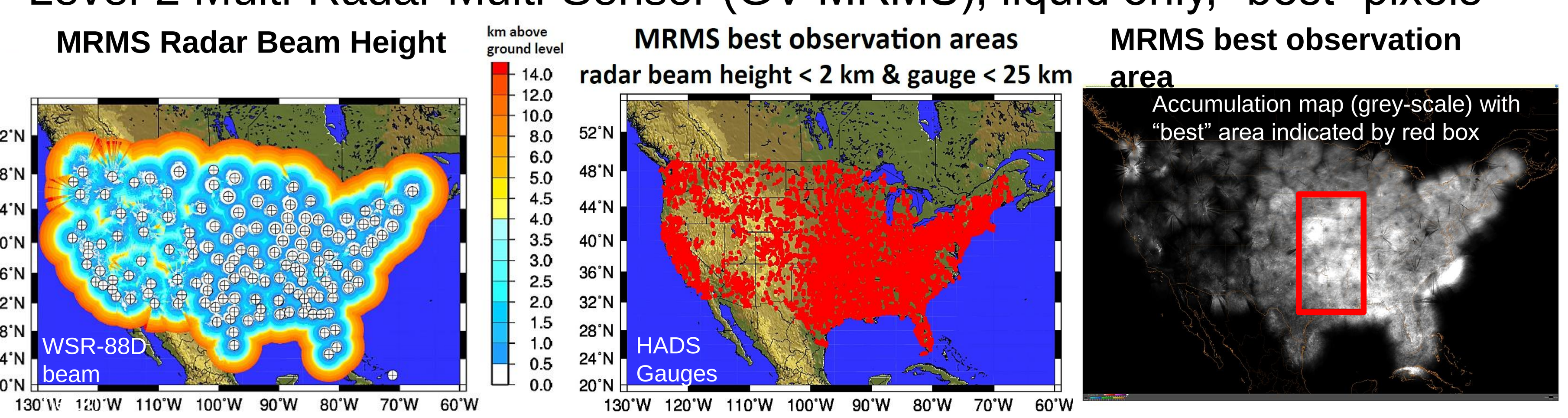


Figure 2. Left: Beam height at lowest elevation angle; center: HADS gauges used in MRMS; right: optimal MRMS area for observational comparisons based on beam height and distance to nearest gauge. NUBF: >80 % coverage.

- OCEAN: Tropical and mid-latitude orbit-coincident Dual-pol radar RR estimation from Kwajalein Atoll and Middleton Island, Alaska. (Liquid only)
- Bias, MAE/RMSE. *For CONUS (ocean), MRMS (radar)* matched FOVs over 50 km grid (DPR, GMI FOVs for bias with up-scaled RMSE to 50 km)
- NUBF impacts: Rain pixels fill at least 80% of FOV, 50% > 0 mm/hr at 50 km;
- GPROF Radiometer estimate: Probability of Precipitation > 40%
- 5th/95th % outliers removed; error variance subsraction applied.
- Select/targeted high quality regional radar datasets (e.g., DFW CASA) for added quality checks. (not shown)

DSD- Drop Size Distribution (Mass-weighted mean diameter: D_m):

- Dual-pol radar-based retrievals of D_m applied to ~70 radars in U.S. using GPM Validation Network software for geometric match to DPR overpasses

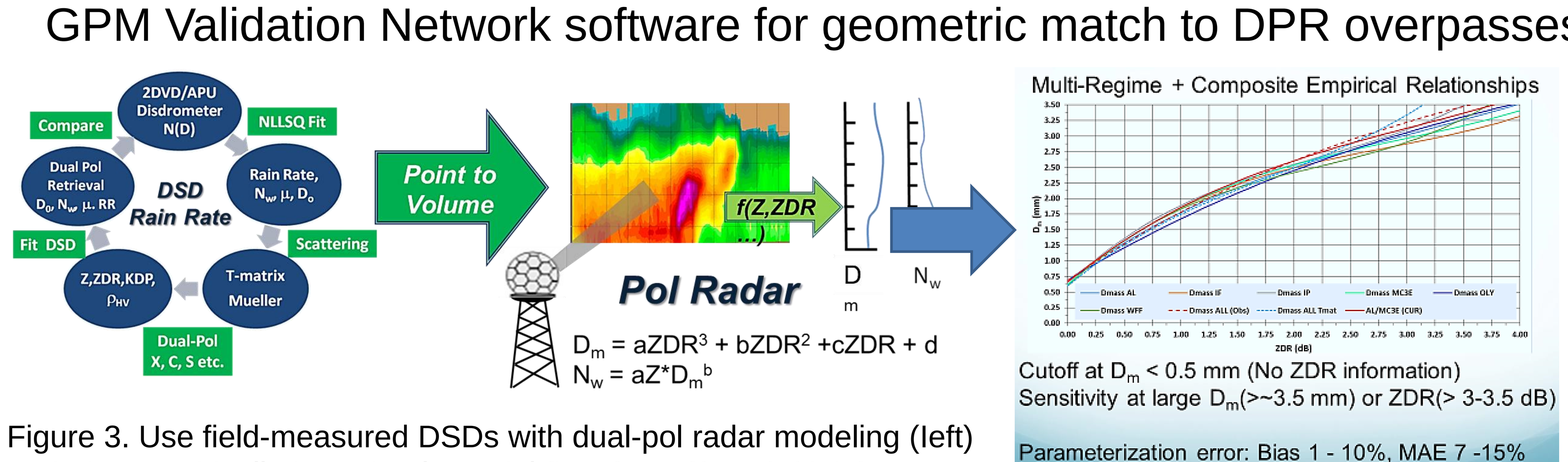


Figure 3. Use field-measured DSDs with dual-pol radar modeling (left) to derive empirically-based polynomial fits of D_m=f(ZDR) (right)

Snow Detection: (Note: No water equivalent rate constraints!)

- GPM Microwave platforms (e.g., GMI) matched to MRMS-defined snow (beam heights below 1.5 km; Surface WB Temp < 0°C).
- GMI POP 40%, <50 Liquid precip fraction (also Combined Alg.);
- DPR "phase near surface"; new "snow index" based for V5 (not shown)
- Supplemental use of METAR or like databases (not shown)

3. Results

Instantaneous Rain Rate: CONUS (MRMS) 50 x 50 km^2 areas

Mar. 2014-Sep. 2015

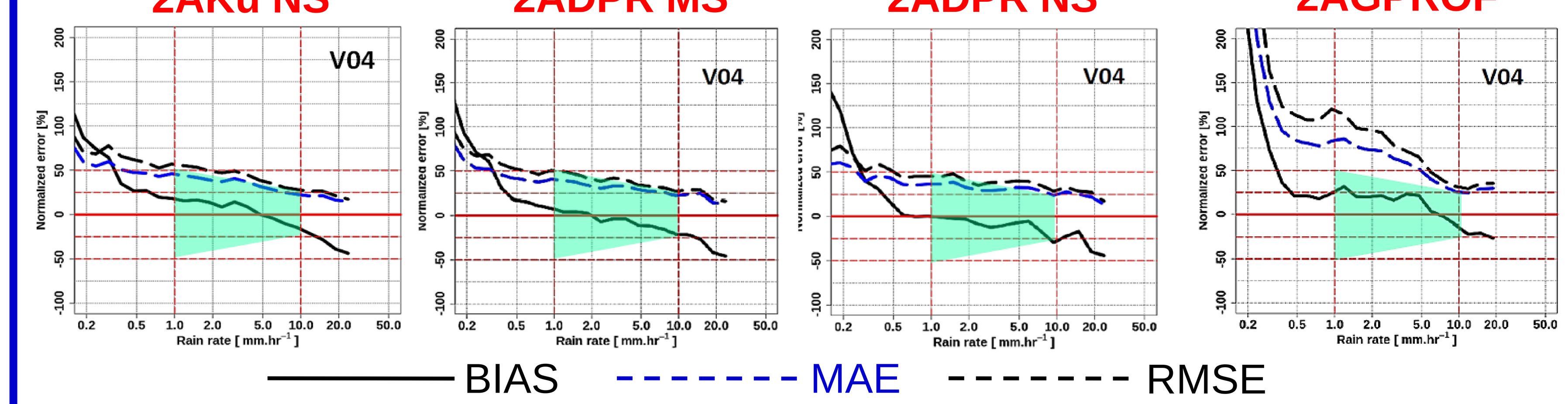


Figure 5. Bias and random errors (MAE and RMSE) for footprints averaged over 50 km areas for Ku normal swath (NS), DPR Ku NS, DPR Ku/Ka matched swath (MS), and GPROF products. Green polygons outline requirement boundary for 1 and 10 mm/hr. Note departure of GPROF from L1 requirements in random error at light rain rates.

Ocean: Kwajalein Atoll (KWAJ) and Middleton Island AK (PAIH)

March 2014 – June 2016

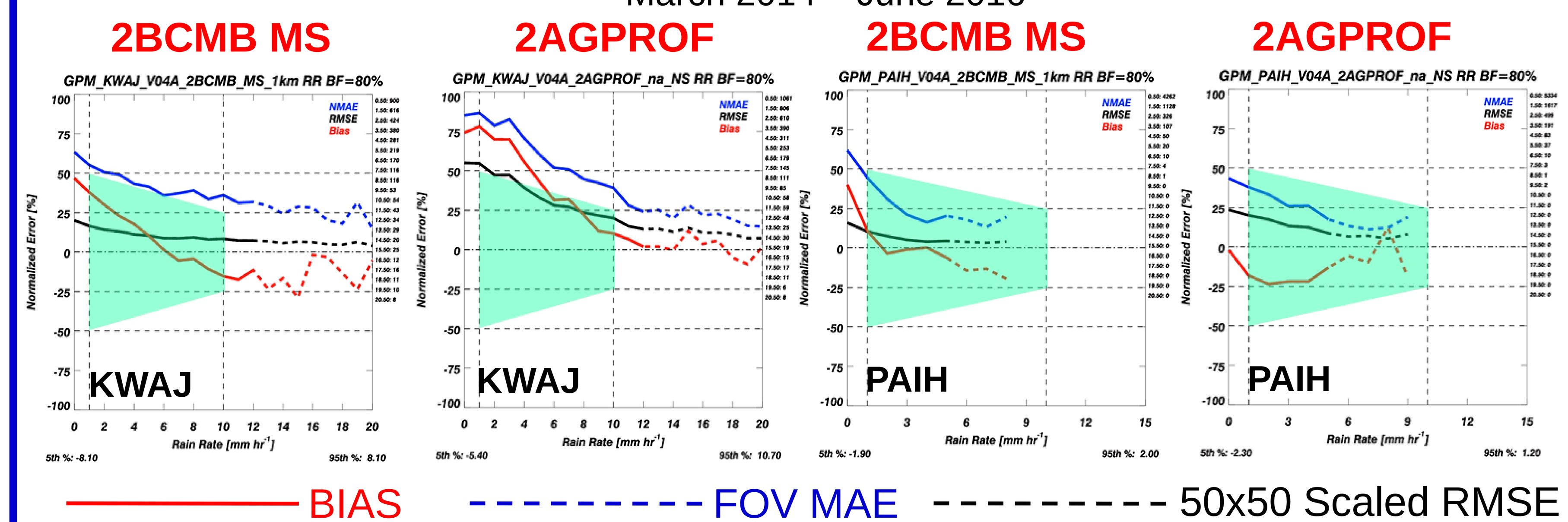


Figure 6. As in Figure 5 but for 2BCMB and GPROF algorithms only (left: KWAJ ; right: PAIH). DPR and Ku NS swaths (not shown) similar or better than 2BCMB MS. Note: due to oceanic single radar sampling limitations, the bias and MAE traces are *computed at footprint scale 5 km (15 km) for DPR (GPROF)*, with black line representing the *RMSE scaled to 50 km*. Dashed lines indicate rain rates for which sample numbers fall below ~30.

GPM Core observatory meets L1 rain rate science requirements based on Combined and DPR radar algorithm performances

Snow Detection at effective FOV (MRMS coincidences)

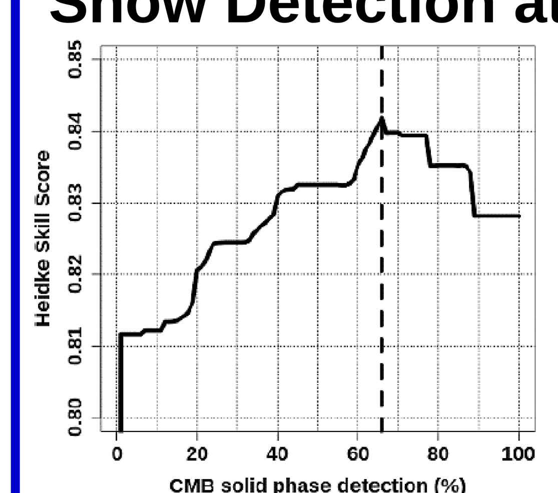


Figure 7. DPR CMB MS vs. MRMS HSS as f(solid phase fraction);

HSS> 0.81, POD=89%, FAR=4%

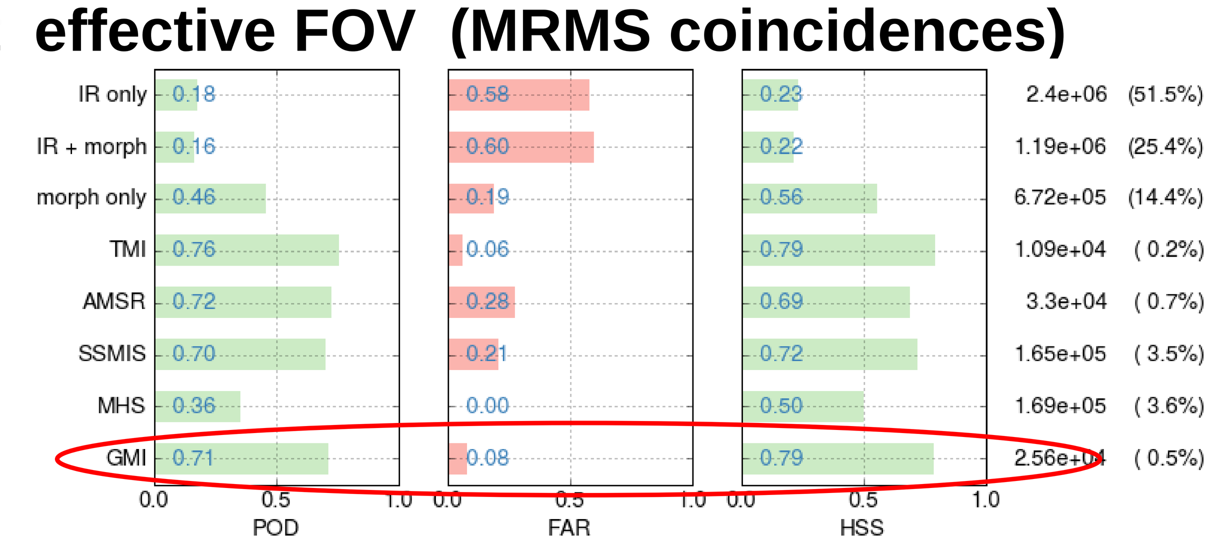


Figure 8. GPM microwave platform snow statistics vs. MRMS. Platform data taken from IMERG data files.

GMI POD=71%, FAR=8%, HSS = 0.79

DPR and GMI "demonstrate detection of snow".

Detection threshold and accurate estimation of SWER are topics of study

DSD (D_m) comparisons

2ADPR NS D_m vs. Ground Radar

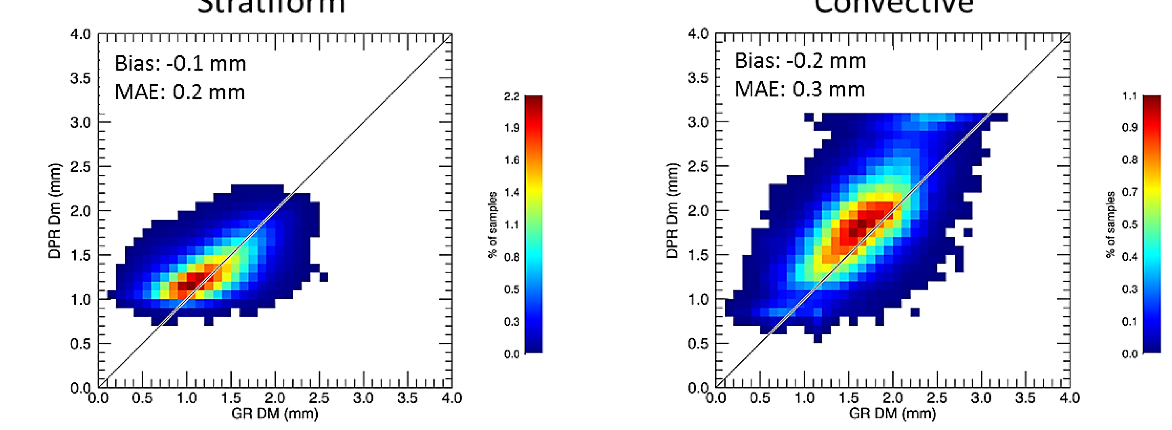


Figure 7. Validation Network (60+ radar) comparison between the 2ADPR NS algorithm V-4 and GV radar estimates of D_m for stratiform (left column) and convective (right column) precipitation. ~80% of total samples are stratiform- so, stratiform behavior strongly weights the final L1 result.

2ADPR NS D_m biased slightly larger (0.1 mm) than GV; well within +/- 0.5 mm for majority of sample; behavior at high D_m in convective precipitation is curious……

2BCMB MS D_m vs. Ground Radar

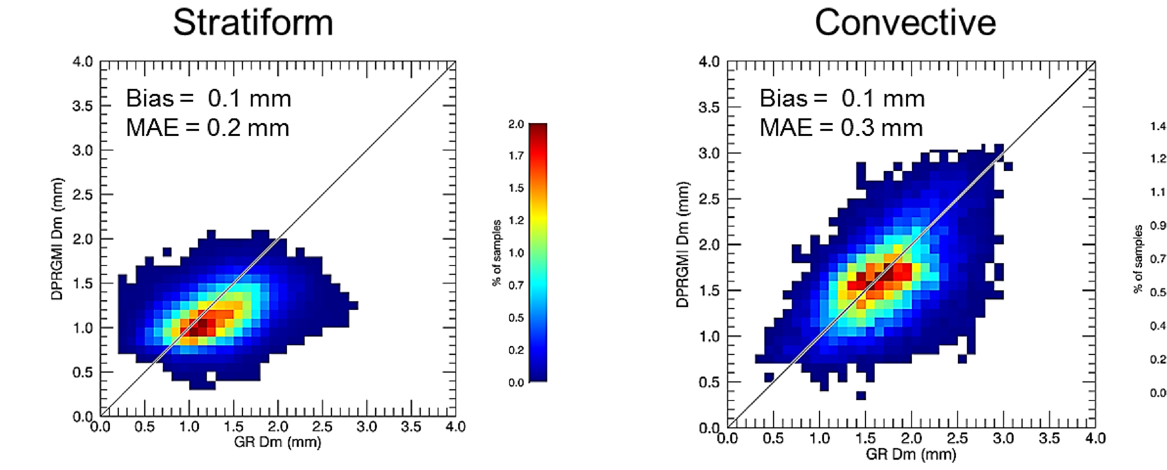


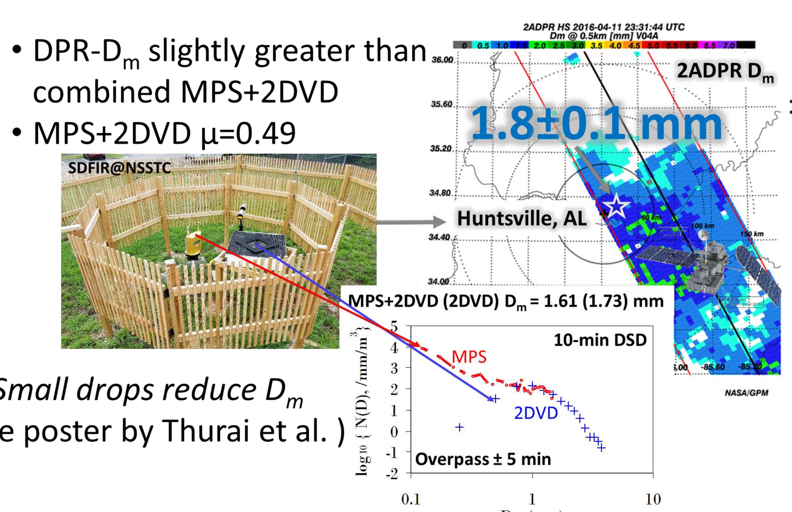
Figure 8. As in Figure 7 but for 2BCMB MS.

2BCMB MS D_m slightly lower (0.1 mm) than GV, but well within +/-0.5 mm of GV for majority of sample.

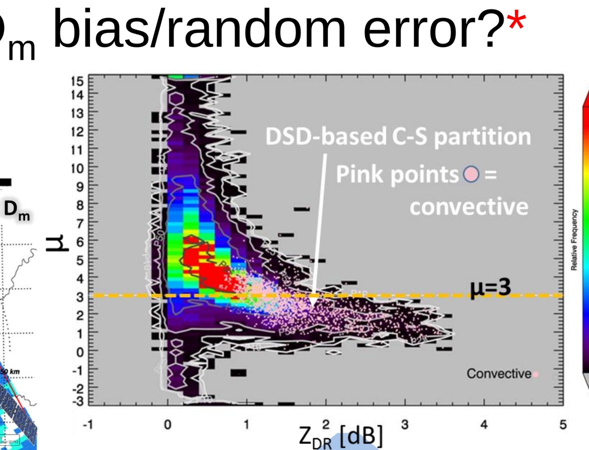
Potential contributors to D_m bias/random error?*

Small drop sampling

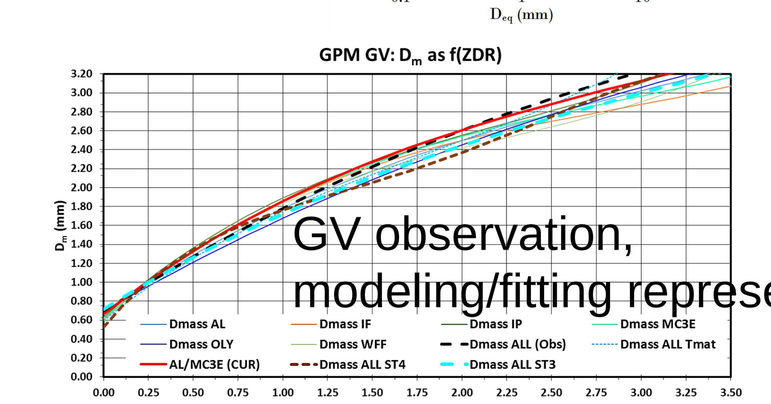
- DPR-D_m slightly greater than combined MPS+2DVD
- MPS+2DVD μ=0.49

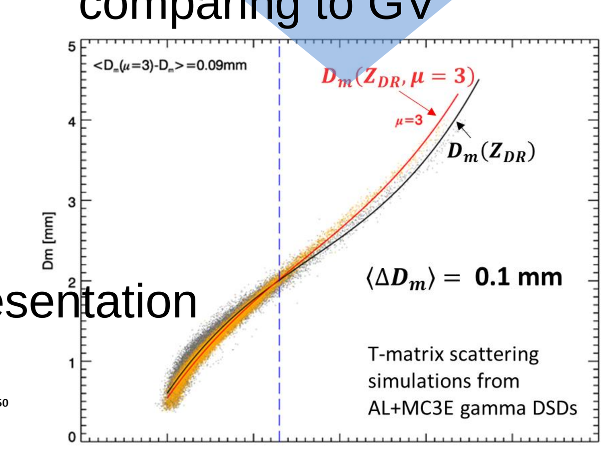


→*Small drops reduce D_m* (see poster by Thurai et al.)



Fixed μ in algorithms- can impact D_m bias when comparing to GV





*assuming no artifacts from GV volume to DPR VN matching...

4. Summary

- GPM appears to meet Level 1 science requirements for RR estimation based on the strong performance of its DPR and KU radar algorithms. Changes in V5 CMB and GPROF radiometer algorithms (e.g., over land) from V4 should improve L1 performance.
- L1 demonstration of snow detection largely verified but at unknown SWE rate threshold (likely < 0.5 – 1 mm/hr liquid equivalent). Ongoing work to improve SWE rate estimation for both satellite and GV remote sensing.
- DSD retrievals (D_m) appear to meet L1 requirements. Source(s) of observed small biases (nature vs. approach) under study.

Acknowledgements: NASA PMM Science Team funding via Dr. Ramesh Kakar, GPM GV funding via Dr. Mathew Schwaller. Mr. Kenneth (Bob) Morris, GSFC, is gratefully acknowledged for application of the VN database to the DSD comparisons shown herein.