GPM Level 1 Science Requirements: Science and Performance Viewed from the Ground

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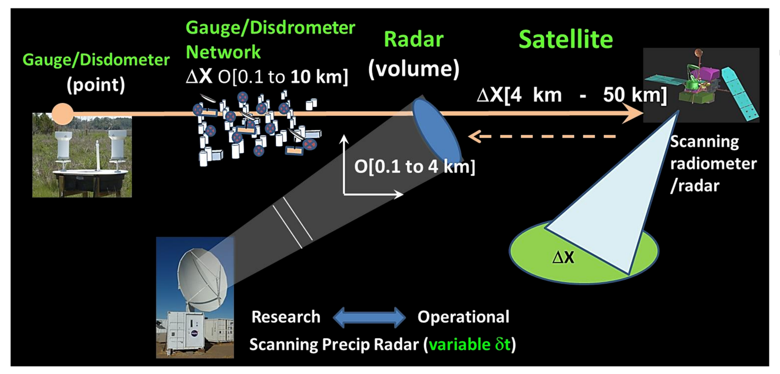
1. Objective: Validation of GPM Core Science Requirements

- 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 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

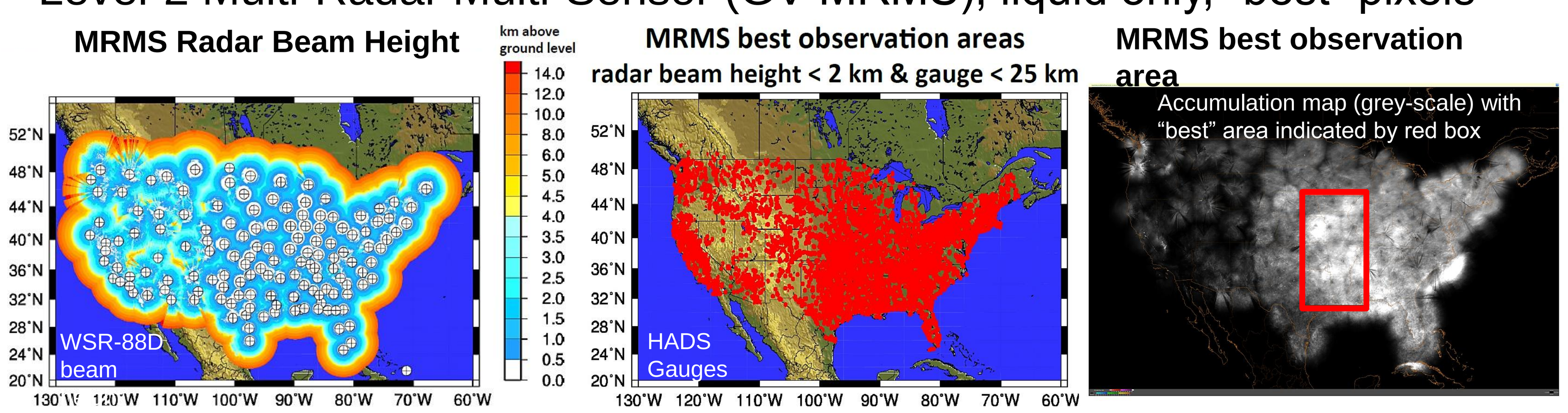
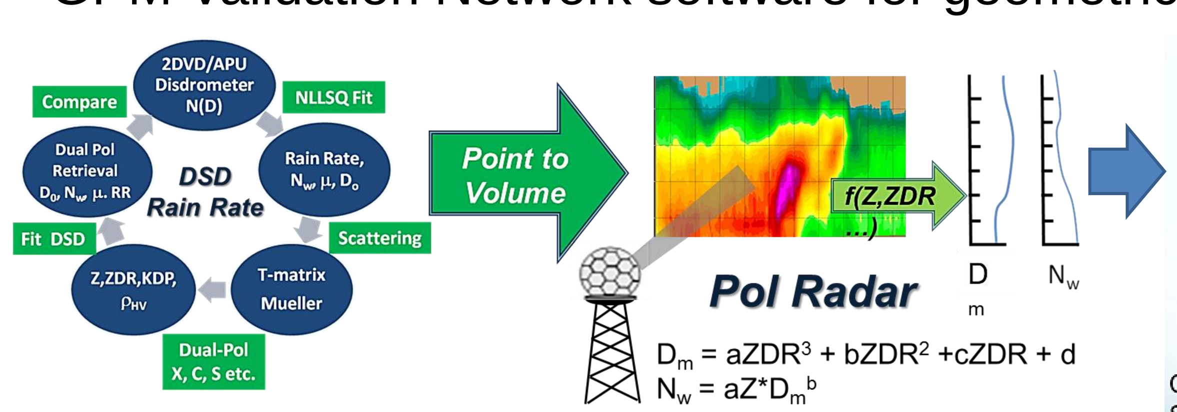


Figure 2. Left: Beam height at lowest elevation angle; center: HADS gauges used in MRMS; right: optimal MRMS area for observational comparisons based on beam height and distance to nearest gauge.

- 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 > 80% of FOV, 50% > 0 mm/hr at 50 km;
- GPROF Radiometer estimate: Probability of Precipitation > 40%
- 5th/95th % outliers removed; error variance subtraction 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



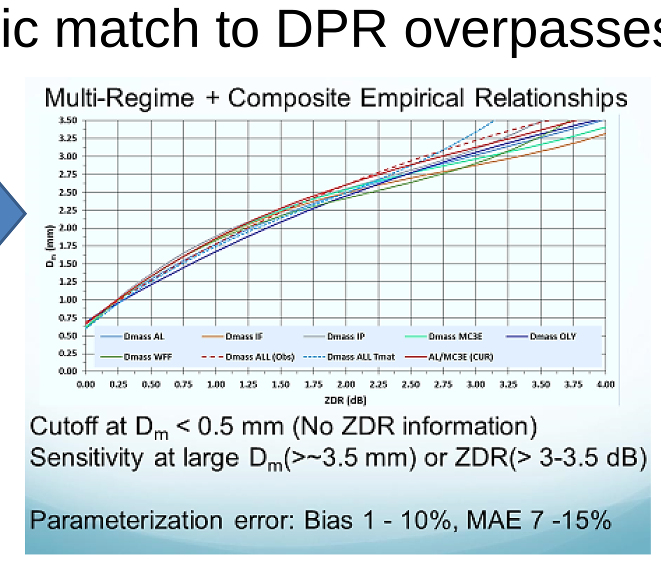


Figure 3. Use field-measured DSDs with dual-pol radar modeling (left) to derive empirically-based polynomial fits of D_m=f(ZDR) (right);

Snow Detection: (water equivalent rate > 0 mm/hr)

- GPM GMI (and other) matched to MRMS-diagnosed snow (beam height below 1.5 km; Surface WB Temp < 0ºC).
- DPR "phase near surface"; new "snow index" based for V5 (not shown)
- Supplemental use of IMERG for multi-platform view, international datasets for detection and water equivalent, METAR or like databases (not shown)

3. Results

A) Instantaneous Rain Rate: CONUS (MRMS)

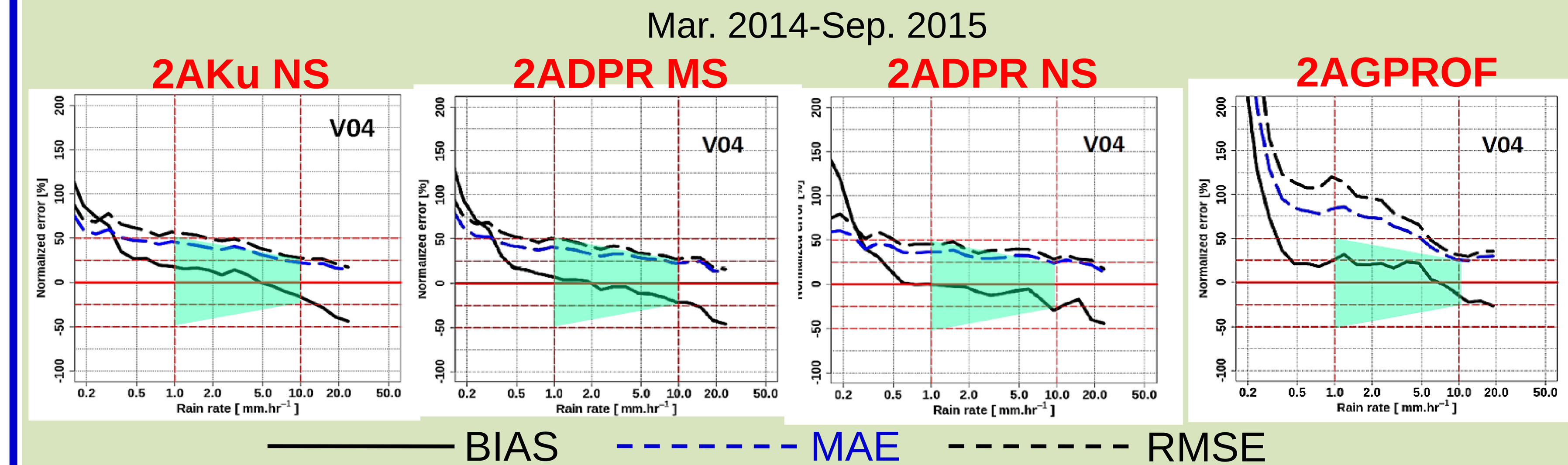


Figure 4. Bias and random errors (MAE and RMSE) for footprints averaged over 50 km areas for V4 Ku normal swath (NS), DPR Ku NS, DPR Ku/Ka matched swath (MS), and GPROF products. Green polygons outline requirement boundary for 1 and 10 mm/hr. Note departure of GPROF from L1 requirements in random error at light rain rates.

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

March 2014 – June 2016

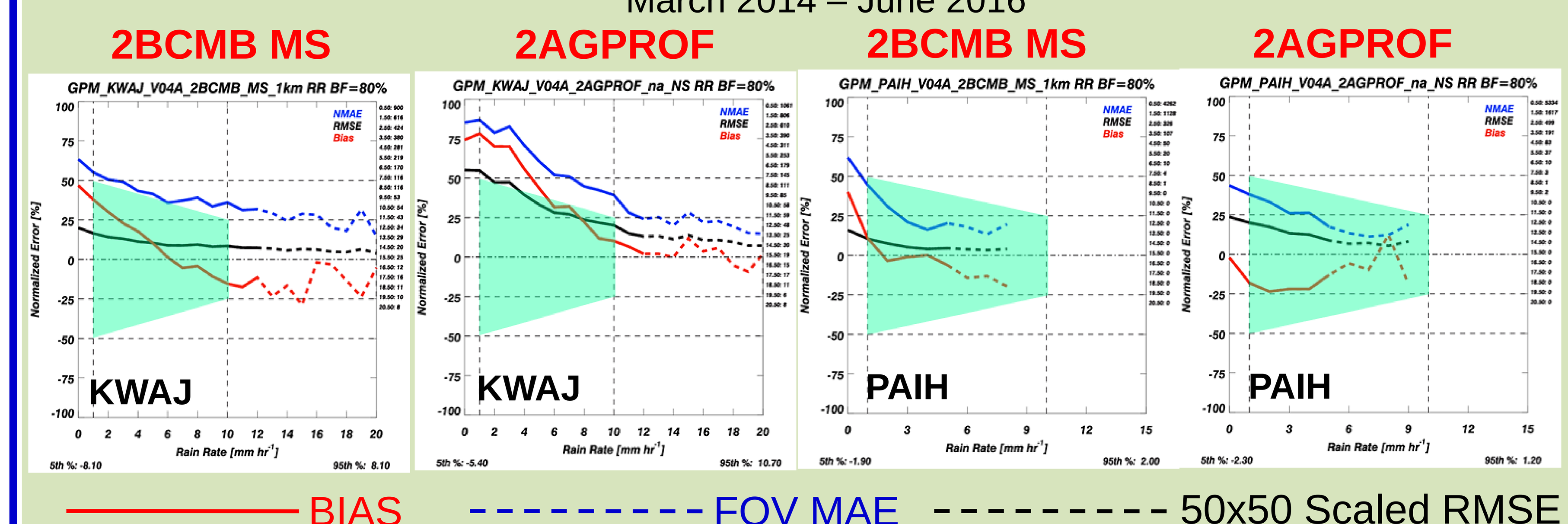


Figure 5. As in Fig. 4 but for 2BCMB and GPROF only (left: KWAJ ; right: PAIH). DPR and Ku NS swaths (not shown) similar or better than 2BCMB MS. Note: due to oceanic single radar sampling limitations, the bias and MAE traces are *computed at footprint scale 5 km (15 km) for DPR (GPROF)*, with black 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

B) Snow Detection

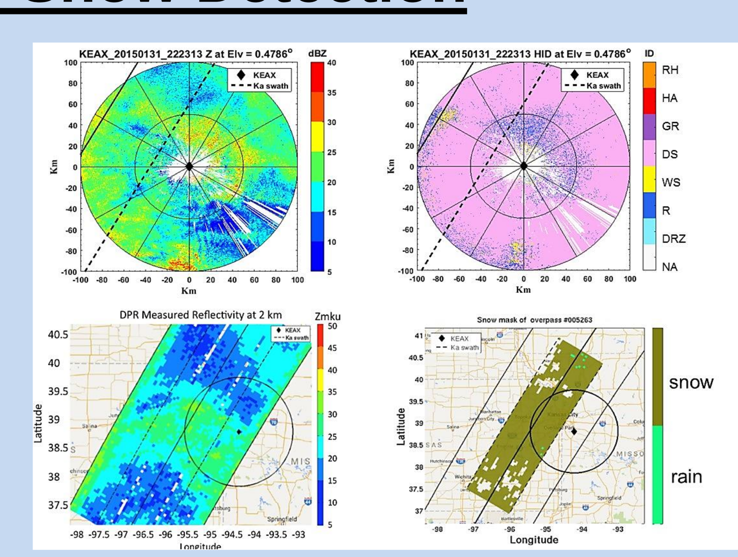


Figure 6. Version 5: New DPR MS (DFR) snow-Index (Lee and Chandrasekar algorithm vs. 88D HID

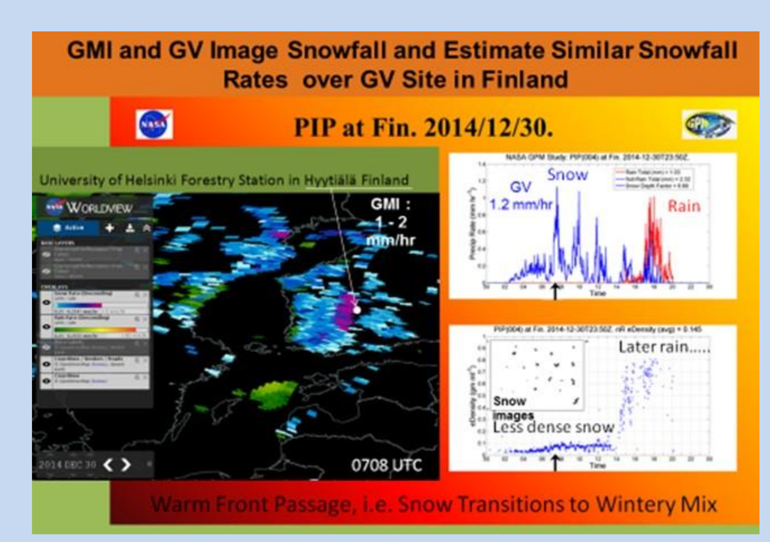


Figure 7. Detection and a reasonable snow water equivalent (SWER) estimate: GMI and PIP Instantaneous snowfall rates over Hyytiala, Finland GV site

DPR/GMI vs. GV comparisons *qualitatively* demonstrate snow "detection"

B) Snow Detection (Continued)

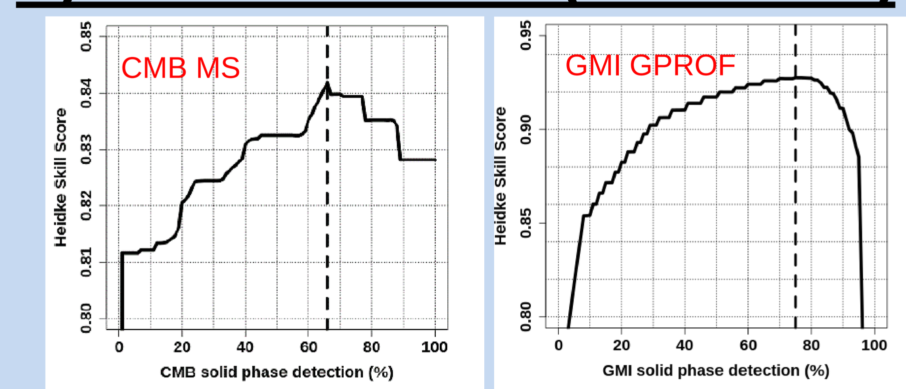


Figure 8. Heidke Skill Score performance for MRMS vs. DPR CMB MS (left; note DPR is similar) and GMI GPROF (right) as a function of % solid phase

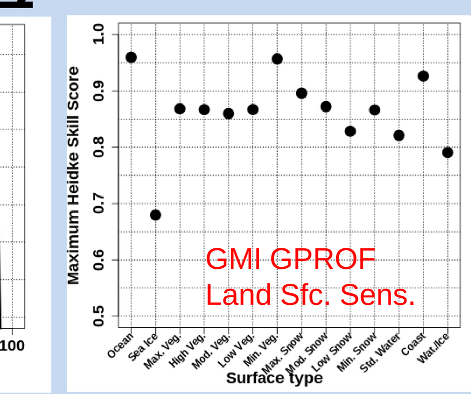


Figure 9. Max GMI GPROF HSS for snow detection f(land surface)

HSS performance statistics *quantitatively* demonstrate snow "detection" relative to the L1 requirement

But, what don't we detect and how well can we measure rates?

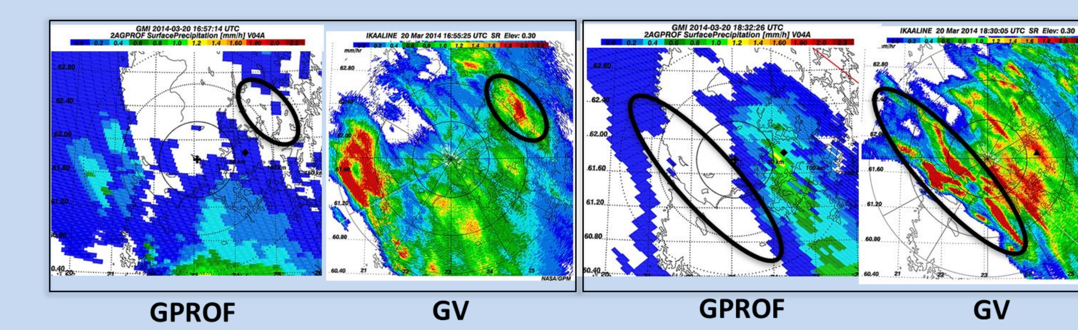


Figure 10. GMI GPROF snowfall water equivalent rates compared to case-specific snow-density and PSD-"tuned" IKA radar-based GV rates in Finland (3/20/2014).

C) DSD (D_m) comparison

2ADPR NS D_m vs. Ground Radar

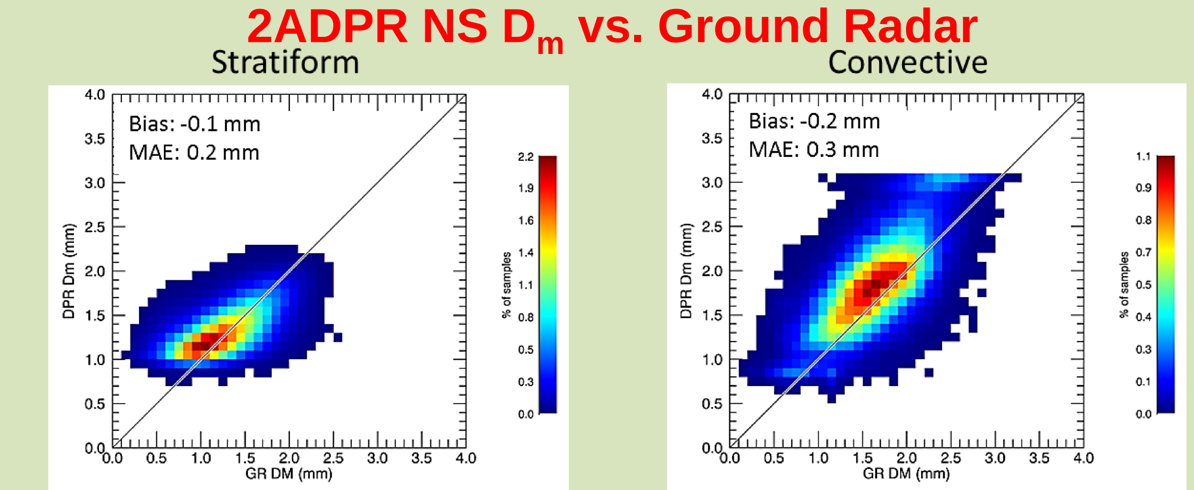


Figure 11. Validation Network (60+ radar) comparison between the 2ADPR NS algorithm V-4 and GV radar estimates of D_m for stratiform (left column) and convective (right column) precipitation. ~80% of total samples are stratiform- so, stratiform behavior strongly weights the final L1 result.

2BCMB MS D_m vs. Ground Radar

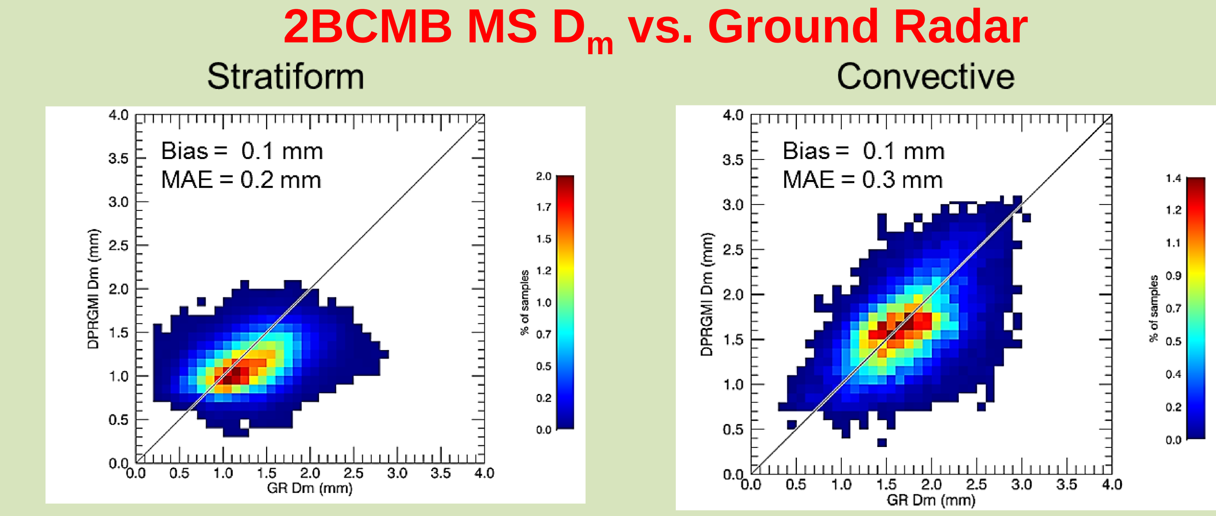


Figure 12. As in Figure 7 but for 2BCMB MS.

DPR (CMB) NS (MS) D_m ~ 1 mm larger (lower) than GV, but well within +/-0.5 mm for majority of sample.

4. Summary

- GPM appears to meet Level 1 science requirements for RR estimation (Sec. 3A) based on the strong performance of its DPR and KU radar algorithms. V5 CMB and GPROF radiometer algorithms (e.g., over land) will improve on L1 performance.
- L1 demonstration of snow detection (Sec. 3B) over non-frozen surfaces 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 (Sec. 3C). Source(s) of small bias (nature vs. approach) under study.

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