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

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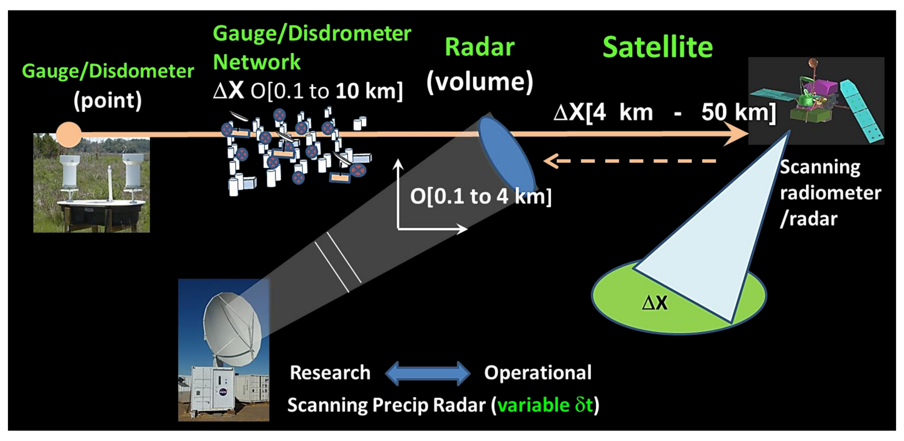
1. GPM L1 Science Requirements for Precipitation Estimation

The Global Precipitation Measurement (GPM) Mission Core satellite platform must meet Level 1 (L1) science requirements:

- GPM Dual-Frequency Precipitation Radar (DPR): *quantify rain rates* between *0.22 and 110 mm hr^{-1}. Demonstrate detection of snowfall* at an effective resolution of 5 km.
- GPM Microwave Imager (GMI): *quantify rain rates* between *0.22 and 60 mm hr^{-1}. Demonstrate detection of snowfall* at effective resolution of 15 km.
- Drop Size Distribution (DSD): 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. Concept and Approaches



Radars bridge point to area FOV/swath

Gauges, disdrometers reference multi-parameter radar retrievals

Figure 1. Radars as a bridge between scales

Satellite FOV Footprint and Area Selection

- 5 km DPR / 15 km GMI footprint "effective" resolution (FOV) assumed
- 50 km x 50 km averages (of footprints), but also computing footprint bias and scaled random error (5 km/15 km footprints to 50 km scale; Steiner et al., 2003 to mitigate sample numbers for rain rates > 10 mm/hr over 50 km scale)

Rain rate:

(1) CONUS: Rain gauge bias-adjusted Multi-Radar Multi-Sensor (MRMS)

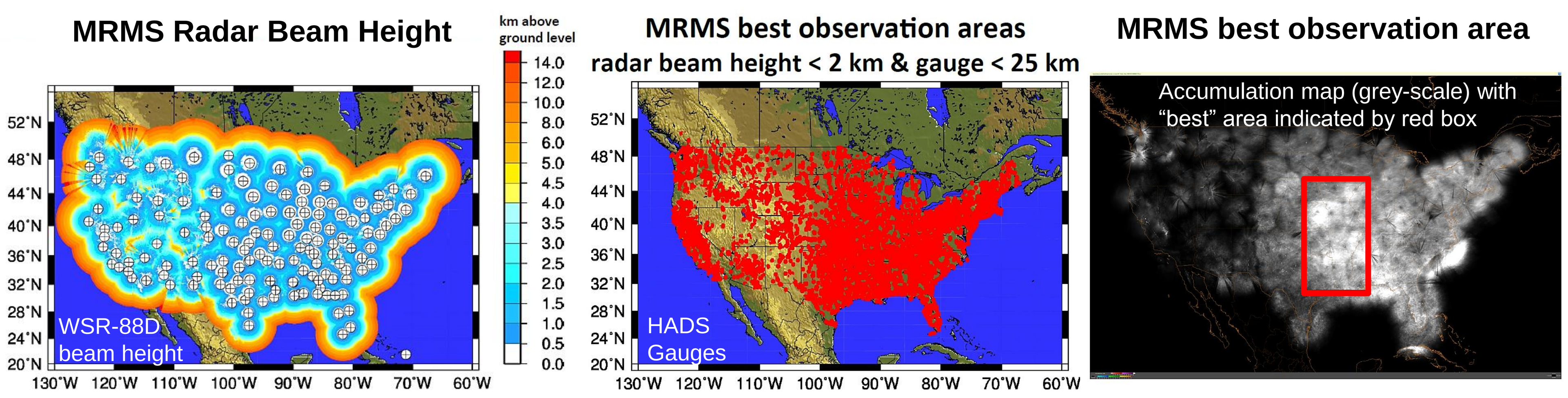


Figure 2. Left: Beam height at lowest elevation angle; center: HADS gauges used in MRMS; right: optimal MRMS area for observational comparisons based on beam height and distance to nearest gauge.

(2) Ocean- Tropical and mid-latitude: Dual-pol rain estimators (range < 100 km) for Kwajalein (tropics) and Middleton Island, Alaska (high-latitude).

- Rain rates estimated at 500 m height
- Scaled footprint RMSE for Ocean radars (mitigate sample number issue)
- Beam filling: pixels fill 80% of FOV, 50% > 0 mm/hr at 50 km;
- GPROF Radiometer estimate: Probability of Precipitation > 40%
- $5^{th}/95^{th}$ % outliers removed

DSD- Drop Size Distribution (D_m):

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

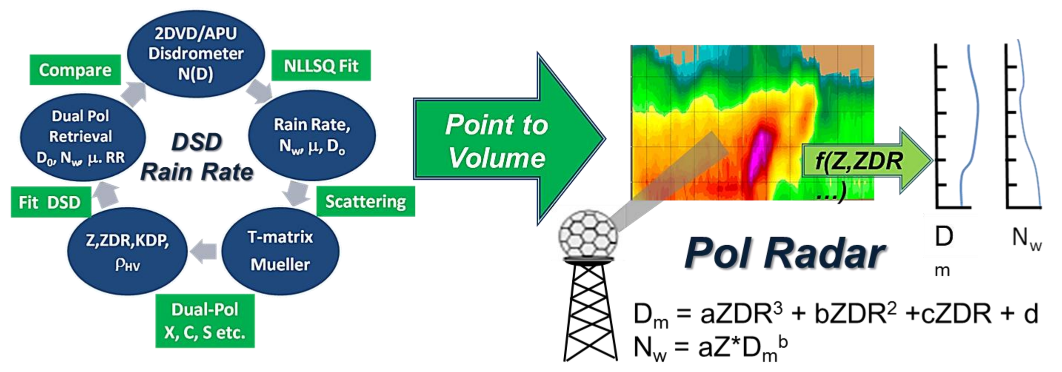
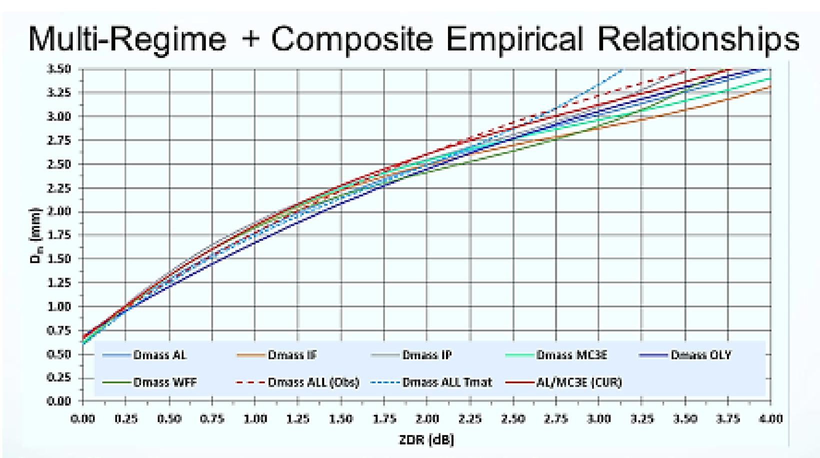


Figure 3. Polarimetric radar DSD modeling

- Robust ZDR-based retrievals



Cutoff at D_m < 0.5 mm (No ZDR information)
Sensitivity at large D_m(>~3.5 mm) or ZDR(> 3-3.5 dB)

Parameterization error: Bias 1 - 10%, MAE 7 -15%

Figure 4. Spectrum of D_m = f(ZDR) polynomial fits from different field campaigns/measurements

- Multi-regime 2DVD DSDs for 6 field efforts
- T-Matrix + fit N(D), and/or Rayleigh-Gans models + observed N(D) for pol variables
- Fit D_m = f(ZDR) (polynomial) for each location and entire dataset

Snow Detection: (Note: no liquid equivalent rate constraints!)

- GPM Microwave platforms (e.g., GMI) in IMERG data files matched to MRMS-defined precip (snow) occurrence.
- L2 files, MRMS-defined snow with 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 km² areas

Mar. 2014-Sep. 2015

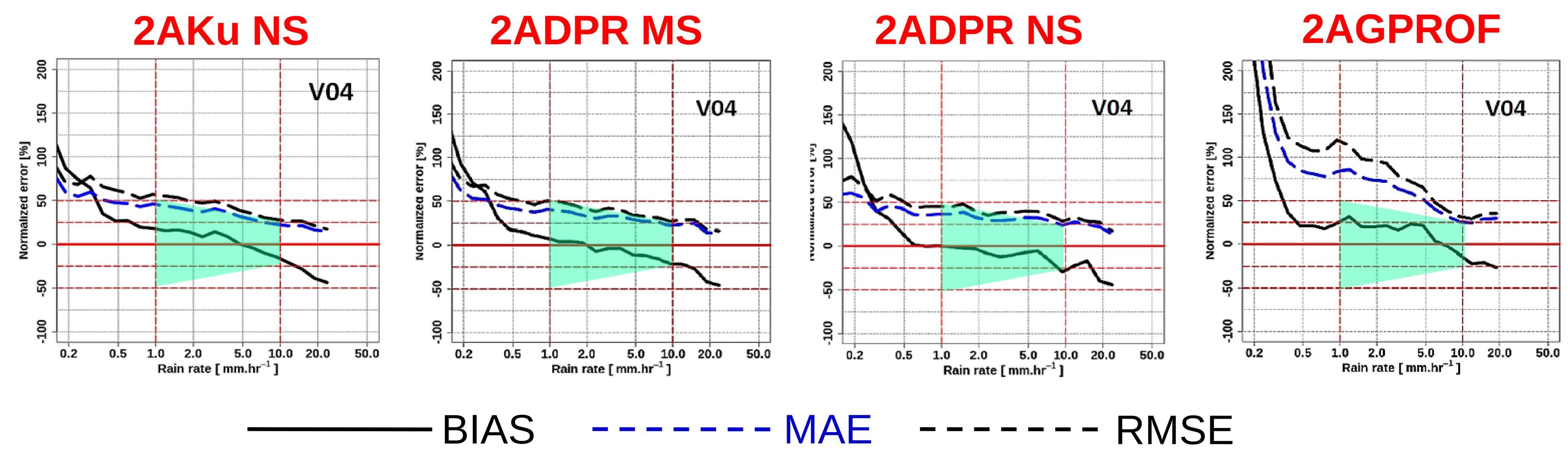


Figure 5. Bias and random errors (MAE and RMSE) for footprints averaged over 50 km areas for Ku normal swath (NS), DPR Ku NS, DPR Ku/Ka matched swath (MS), and GPROF products. Green polygons outline requirement boundary for 1 and 10 mm/hr. Note departure of GPROF from L1 requirements in random error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

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

March 2014 – June 2016

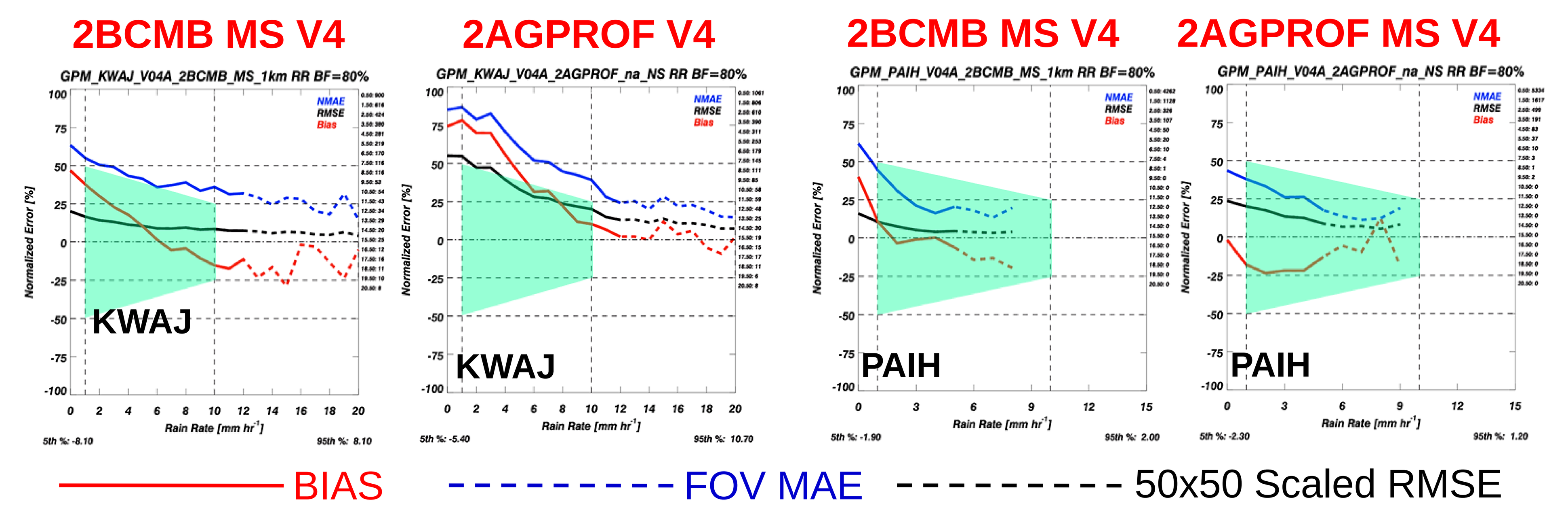


Figure 6. As in Figure 5 but for 2BCMB and GPROF algorithms only (left: KWAJ ; right: PAIH). DPR and Ku NS swaths (not shown) similar or better than 2BCMB MS. Note: due to oceanic single radar sampling limitations, the bias and MAE traces are *computed at footprint scale 5 km (15 km) for DPR (GPROF)*, 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 requirement based on Combined and DPR algorithm performance

DSD (D_m) comparisons

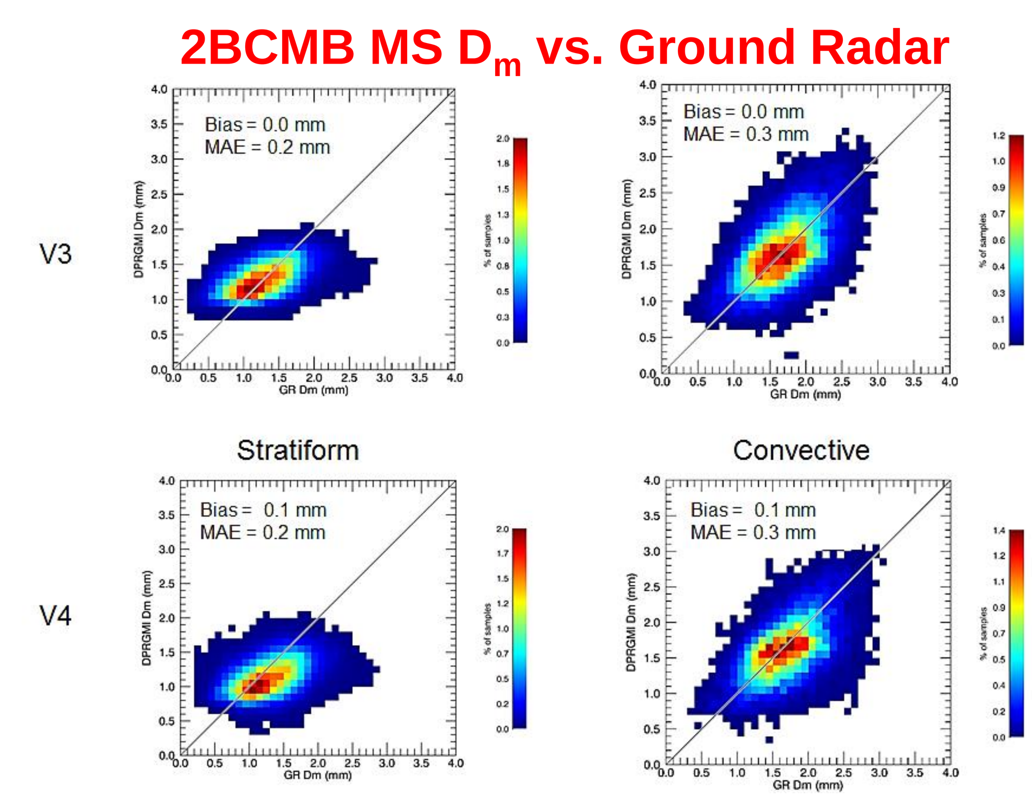
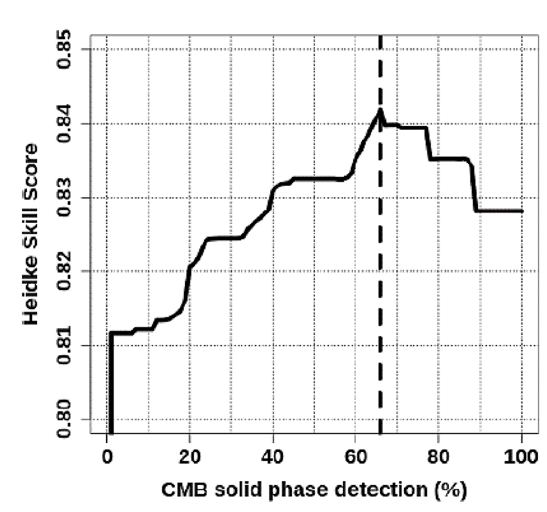
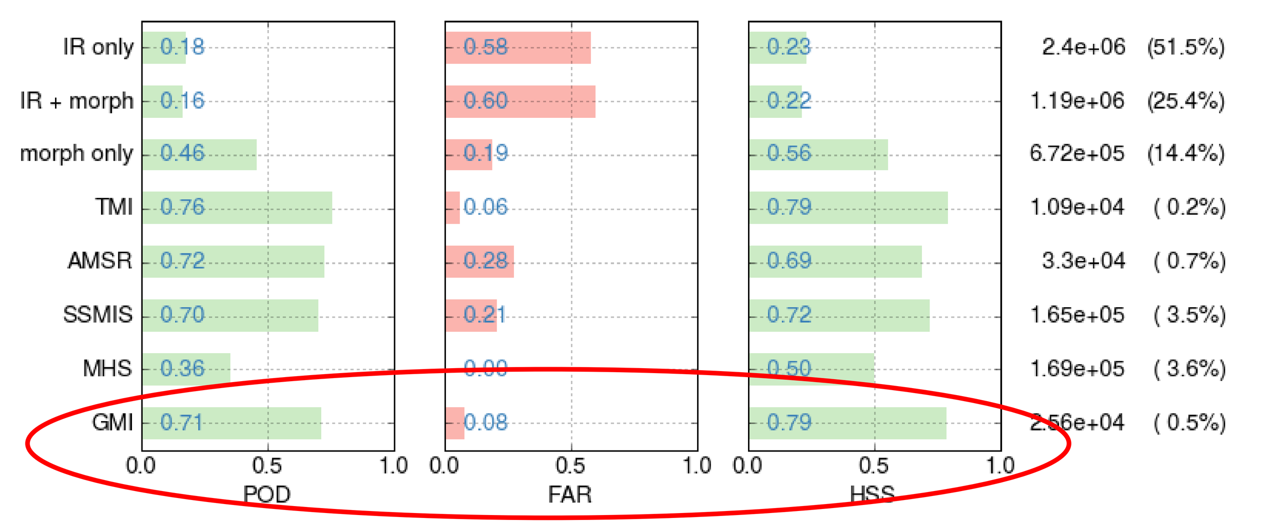


Figure 7. Example shown is for Validation Network comparison between the 2BCMB algorithm Version 3 (top) and Version 4 (bottom) radar-based estimates of D_m vs. DPR for stratiform (left column) and convective (right column) precipitation. 80-85% of total samples are stratiform- so, stratiform will weight final L1 result.

GPM bias + MAE in D_m generally within 0.5 mm of GV for majority of sample.

Snow Detection at effective FOV (MRMS coincidences)





2BCMB MS HSS as f(solid phase fraction) > 0.81 POD = 89%. FAR 4%

GPM GMI Snow statistics show POD=71%, FAR=8%, HSS = 0.79 (Courtesy, J. Tan, NASA GSFC)

We "demonstrate detection of snow", but determining lower detection threshold and accurately estimating snowfall rate, are outstanding problems.

4. Conclusion

- GPM meets Level 1 science requirements for rain estimation based on the strong performance of its radar algorithms. Changes in the V5 GPROF algorithm should correct errors in V4 and will likely resolve GPROF performance issues relative to L1 requirements.
- L1 FOV 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.