Consistent Measurement and Physical Character of the DSD: Disdrometer to Satellite

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1. Objective: Validate GPM Drop Size Distribution Retrievals

- Drop size distributions (DSD) are critical to GPM DPR-based rainfall retrievals.
- NASA GPM Science Requirements stipulate that the GPM Core observatory radar estimation of D_m shall be within +/- 0.5 mm of GV.
- GV translates disdrometer measurements to polarimetric radar-based DSD and precipitation type retrievals (e.g., convective vs. stratiform) for coincident match-up to GPM core overpasses.
- How well do we meet the requirement across product versions, rain types (e.g., C/S partitioning), and rain rates (heavy, light) and is behavior physically and internally consistent?

2. Approach

Overarching method: Multi-regime, global disdrometer DSD "point" measurements are bridged to GPM DPR footprint/swath scales using GV dual-polarimetric radars (national network and Tier-1 research)

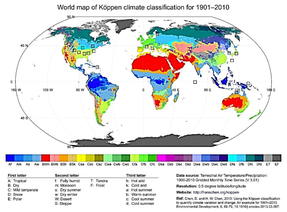


Figure 1. GV global 2D Video Disdrometer (2DVD) point datasets in Köppen Climate Classification. Datasets include GPM GV and partner-donated data.

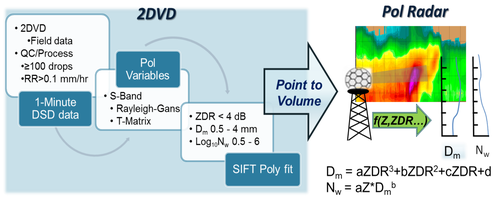


Figure 2: Empirical models for translating between 2DVD DSD and dual-pol radar moments developed for GV field campaign "regimes", then aggregated to "***ALL-regimes***" (> 200,000 minutes used). Fit errors: Bias < 10%, MAE < 15%

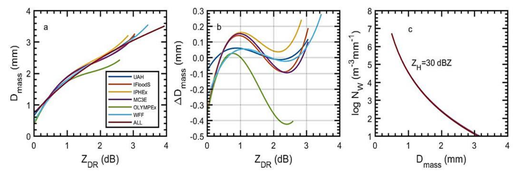
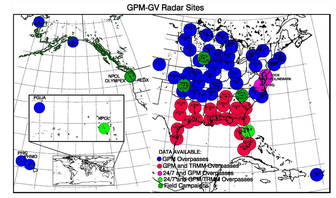


Figure 3. Evaluation of "All" relationship (D_m and N_w) is checked against individual regime behaviors; OLYMPEX regime illustrates care that must be taken in applying single regime 2DVD D_m fits to a global sample.



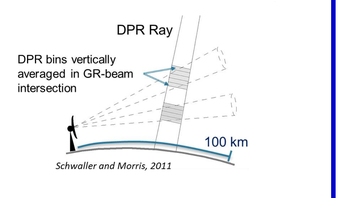


Figure 4. Compute DSDs using 65+ dual-pol radars (left) and >41,000 volume scans and footprint match to GPM DPR (rain-only) using Validation Network (VN) software. Large number of radars and samples helps mitigate bias issues.

3. Results

Continental Scale comparisons confirm GPM meets basic DSD (D_m) science requirement…but……..

Nature?

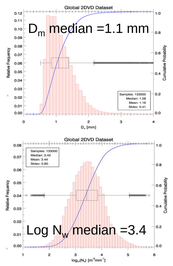


Figure 5. Distribution of D_m (top) and N_w (bottom) from global 2DVD sample. *Challenge for dual-freq. sampling of most common D_m.*

L1 DSD: DPR MS V4, V5 vs. GV Radar D_m

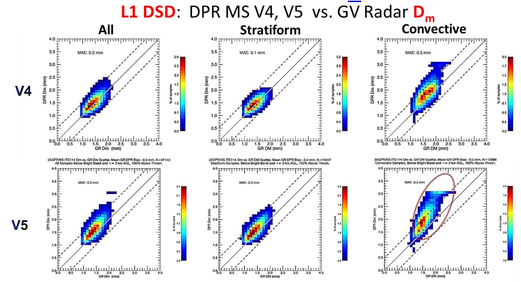
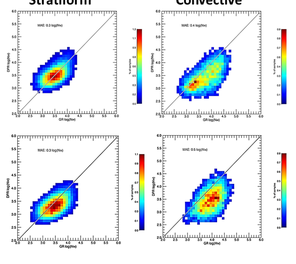


Figure 6- left *DPR D_m meets L1 requirement in V4 and V5, but largely via stratiform behavior.*

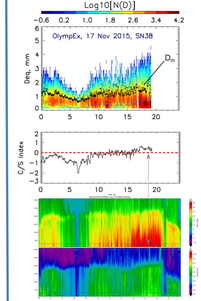
Relative to V4, V5 D_m bias is increased, *convective bias increases more with D_m*; DPR D_m's large compared to "nature", *truncated D_m=3 in DPR MS.*

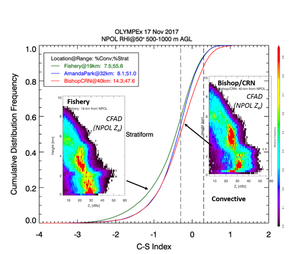
Figure 7- right. The N_w bias trends with GV but there is *an increased low bias in V5 DPR consistent with increasing postive D_m bias*

DPR MS V4, V5 vs. GV Radar N_w



Testing the consistency of DSD-based C/S separation in the challenging environment of OLYMPEX





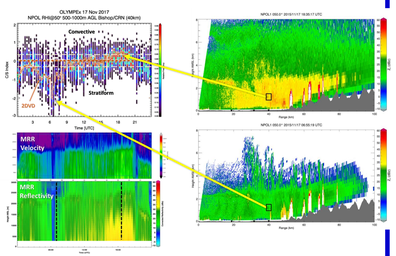


Figure 13. 17 Nov. Atmos. River event. Top: 2DVD DSD with time; middle C/S Index (< 0 = stratiform, > 0 = convective); bottom MRR reflectivity and fall velocity.

Figure 14. *DSD-based C/S is separation broadly consistent with GV radar*. Left: CFADs of RHIs and CDF of C/S Index from NPOL radar. Fishery site upstream and largely in stratiform, Bishop/CRN close to mountains and under low-level convective echo. Middle: C/S index with time from NPOL DSDs with MRR trend (bottom). Right: NPOL RHIs for convective (top) and stratiform (bottom) periods.

Broad physical consistency?

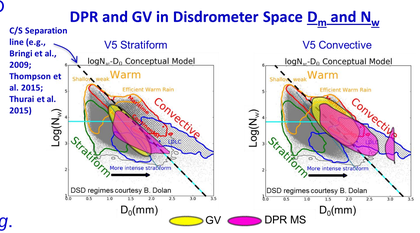


Figure 8. (Left) 2DVD *DSDs used for C/S regime partitioning*, then compared to GPM DPR MS retrievals (underlying gray-shade figure, courtesy Dolan et al. 2017). *DPR C/S generally consistent with 2DVD partitioning.*

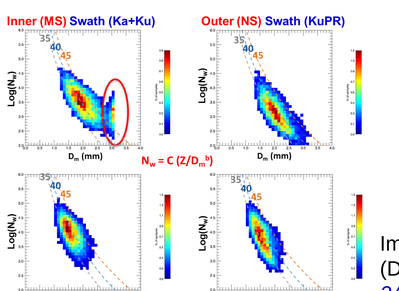


Figure 9. D_m vs. N_w. *Differences (bias and discontinuities in value) between GV, DPR (MS), and outer swath (2AKu) DSDs exist- especially for convective rain*

Impacts on convective rain?

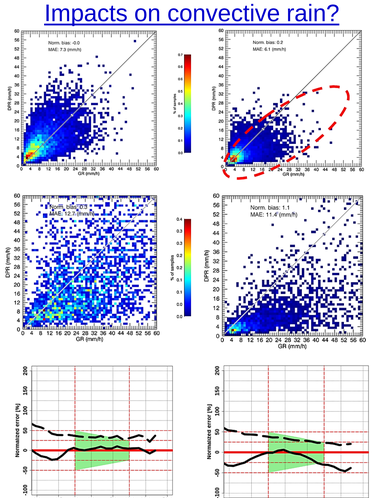


Figure 10. Top- for all D_m, 2ADPR convective rain rate vs. GV for MS (left) and outer-(2AKu; right) rain rate products.

Middle, as above but for D_m > 2.5 mm

As above but L1 50 x 50 km bias (solid) and NMAE (dash) plotted against MRMS rain rates.

Impacts *not as noticeable in DPR MS* except when D_m is large (D_m=3 limits the impact?)- *impacts more noticeable in outer swath-2AKu* (global varying ε) and, *especially at large D_m (small N_w).*

Combined Algorithm?

Broader L1 rain and DSD conclusion similar to DPR, but, *DSD behavior is distinctly different from DPR and GV* (*Figure 11*, as in Figure 10, but Ku+Ka+GMI algorithm swath)

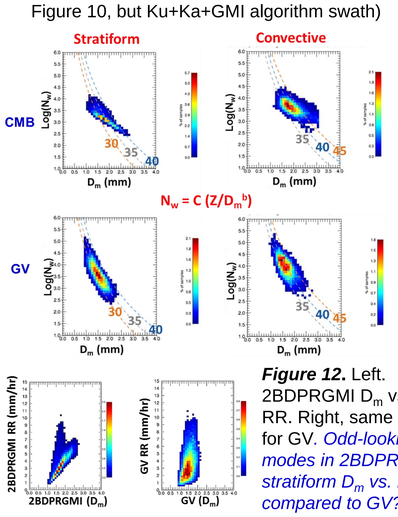
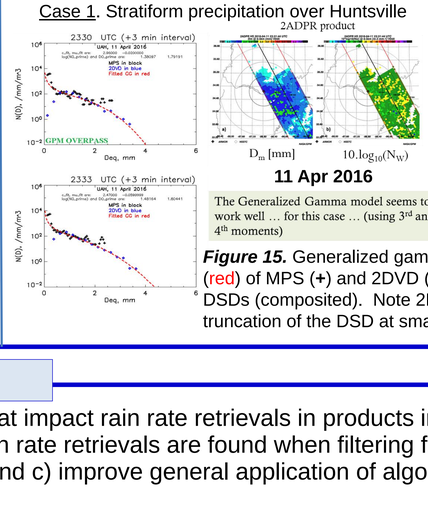


Figure 12. Left. 2BDPRGMI D_m vs. RR. Right, same but for GV. *Odd-looking modes in 2BDPRGMI stratiform D_m vs. RR compared to GV?*

Consistent representation of the DSD to include small D_m and light rain

DPR estimators in light rain tend to underestimate (e.g., Fig. 10, bottom). *The three parameter gamma does not generally fit the DSD well in light rain nor do we measure it well using the 2DVD in small drop sizes*(< 0.6-0.7 mm). Use MPS + 2DVD and *a generalized gamma for this purpose?* Yes! (see below)

Case 1. Stratiform precipitation over Huntsville



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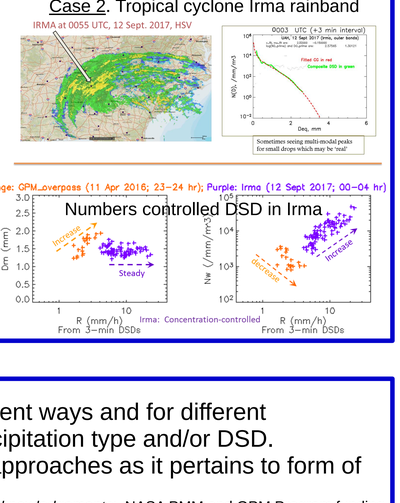
The Generalized Gamma model seems to work well … for this case … (using 3rd and 4th moments)

Figure 15. Generalized gamma fits (red) of MPS (+) and 2DVD (◇) DSDs (composited). Note 2DVD truncation of the DSD at small D.

Case 2. Tropical cyclone Irma rainband



4. Summary

GPM DSD retrievals satisfy basic science requirements. However some inconsistencies between GV, DPR and Combined algorithm retrievals exist in V5 that impact rain rate retrievals in products in different ways and for different precipitation types. Underlying physics of DPR DSD behavior seem consistent with GV, but Combined algorithm retrievals behave differently. Impacts to rain rate retrievals are found when filtering for precipitation type and/or DSD. Continued validation of algorithm retrievals and GV approaches is required to a) verify consistent physics; b) assure the right answer for the right reasons; and c) improve general application of algorithm approaches as it pertains to form of the DSD (e.g., gamma vs. generalized gamma vs. ?).

Acknowledgements: NASA PMM and GPM Program funding