Consistency Check of GPM DPR Snow Estimates

Liang Liao
MSU, Greenbelt, MD

Robert Meneghini
NASA/GSFC, Greenbelt, MD

Hyokyung Kim
MSU, Greenbelt, MD

Introduction

The objective of the present study is to check the consistency of the DPR snow retrieval by comparing the DPR standard products with those inferred by the standard dual-frequency technique that is in principle independent of the DPR operational algorithm. The DPR dual-frequency algorithm employs an adjustable R-D_m relation for the profiling retrieval. The same R-D_m relation is applied for liquid, solid and mixed-phase hydrometeors within the profiles. A detailed description of the DPR algorithm is documented by Seto et al. (2020). The standard dual-frequency technique makes use of the Ku- and Ka-band dual-frequency ratio (DFR), hereinafter referred to as DFR-based approach, and infers snow parameters on the gate-by-gate basis. As snow attenuation is relatively small at both frequencies, the estimate at one range gate is nearly independent of the other gates, which is in contrast to the DPR algorithm that relies on measurement of the entire profile in order to determine the optimal R-D_m relation. The accuracy of the DFR-based estimates has recently been evaluated through a simulation study using measured PSD. It is found that the DFR-based approach is reasonably accurate in estimates of liquid-equivalent snowfall rate (R) and D_m.

In this study, to ensure that the data are taken in snow, the DPR measurements are selected exclusively from those with well-defined bright-bands using data from between 0.5 to 3 km above the top of the bright-band. Inner-swath data from Version-6 snow products from the 16 orbits of 1 January 2020 are compared with snow estimates obtained from the DFR-based approach using measured Ku- and Ka-band reflectivities.

Acknowledgments: This work was supported by Dr. G. D. Skofronick-Jackson of NASA Headquarters under NASA's Precipitation Measurement Mission (PMM) Grant NNH18ZDA001N-PMMST. The authors also wish to thank Dr. K-S. Kuo of University of Maryland and Dr. G. Liu for providing the scattering databases.

DFR-Based Retrieval LUT

Assuming liquid-equivalent PSD: $N(D) = N_W f(\mu)\left(\frac{D}{D_m}\right)^{\mu} \exp(-\Lambda D),$

Radar reflectivity factor: $Z_e = \frac{\lambda^4}{\pi^5 |K_w|^2} \int_0^\infty N(D)\sigma_b(D,\lambda)dD,$

Differential frequency ratio (DFR): $DFR = 10\log(Z_{Ku}/Z_{Ka})$

Snow water content: $SWC = \int_0^\infty N(D)m(D)dD$

Liquid-equivalent snow rate: $R = \frac{36\times10^{-4}}{\rho_w}\int_0^\infty N(D)m(D)V(D)dD$

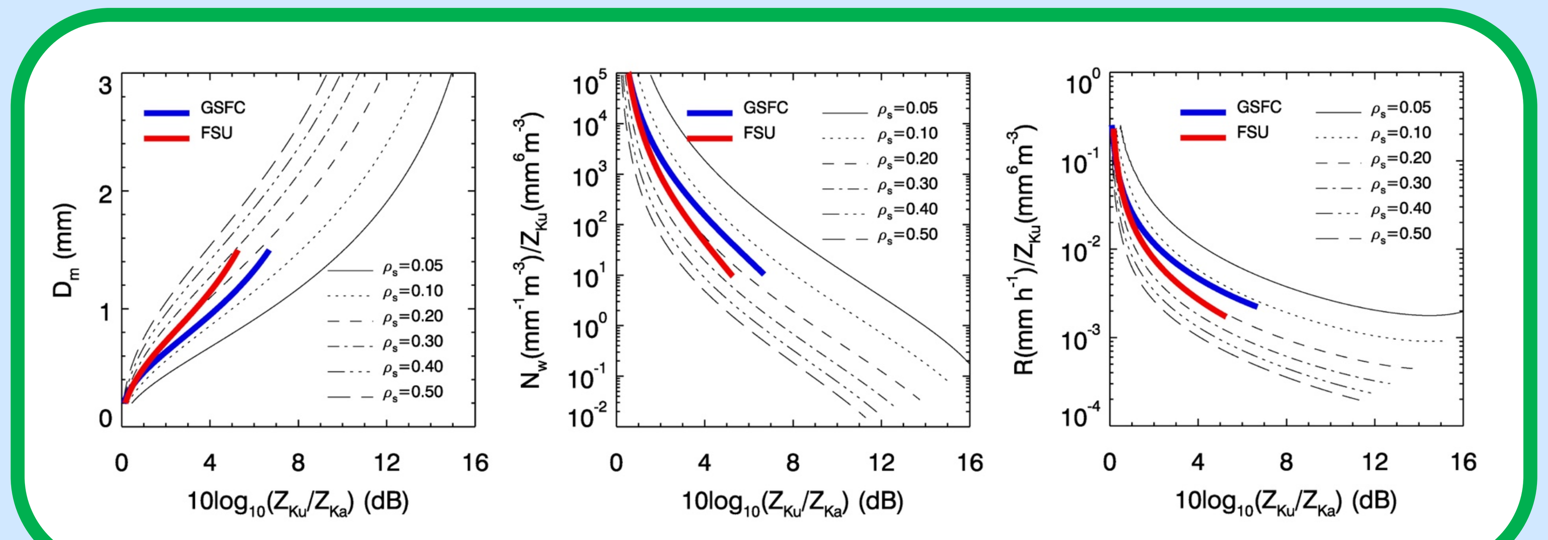

Fig.1 Snow retrieval look-up tables in which N_w (middle) and R (right) are normalized by the Ku-band radar reflectivity Z_{Ku}, and D_m (left) is expressed as a function of DFR (=10log$_{10}$(Z_{Ku}/Z_{Ka})). For these computations, the gamma PSD model with a fixed μ of 0 is assumed. The results from the GSFC and FSU scattering databases are denoted by the heavy blue and red solid curves, respectively. Also provided are the results from the spheroidal model with the snow densities ranging from 0.05 to 0.5 g/cm^3 (thin black curves) for reference.

DPR Snow Data

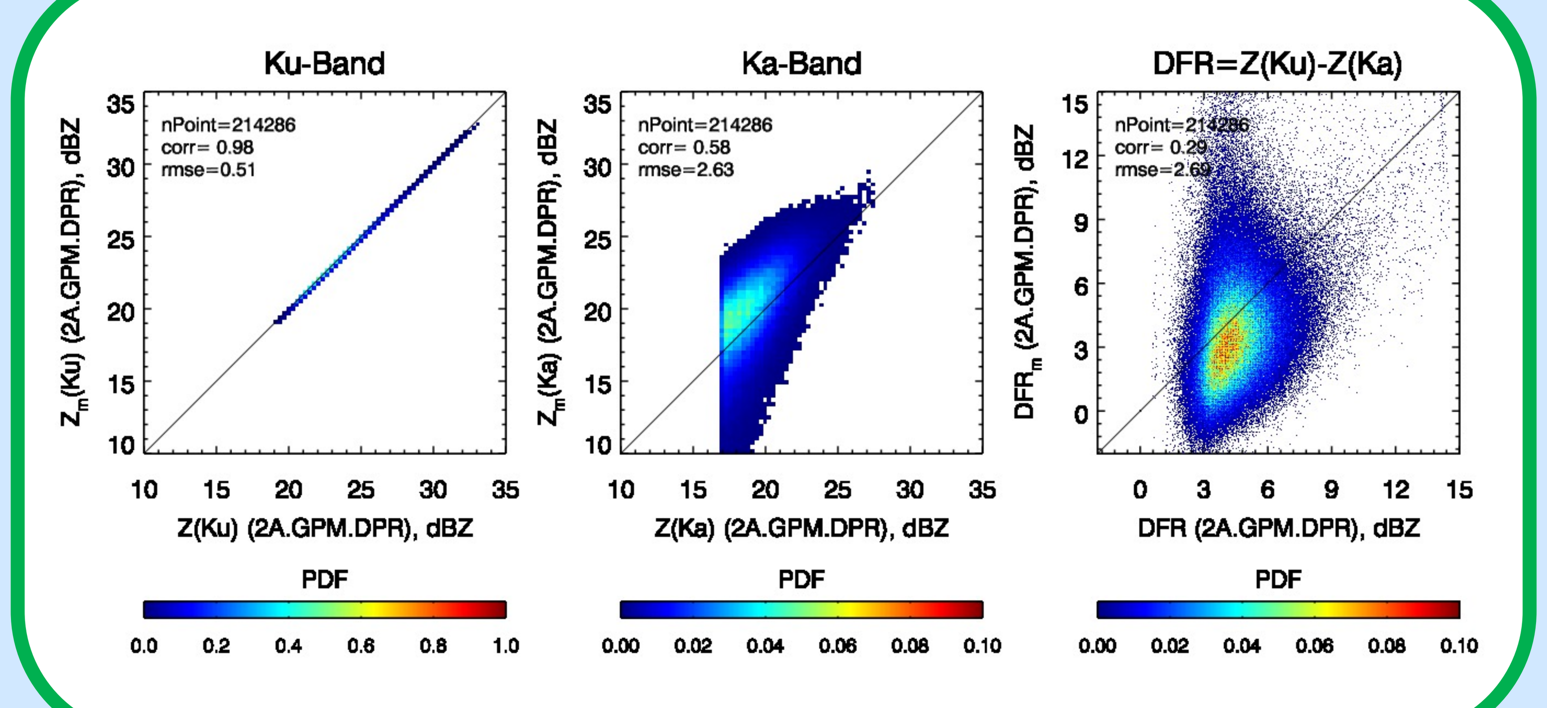

Fig.2 Comparisons of measured Ku- (left) and Ka-band (middle) reflectivities and DFR (right) of snow with their respective attenuation-corrected reflectivities and DFR. The data are taken from the DPR V6 standard product (2A.GPM.DPR) on 1 January 2020 with a total of 16 orbit measurements. It is expected that there shouldn't be much differences between measured and attenuation-corrected reflectivities and DFRs as a result of relatively small snow attenuation. This is obvious at Ku-band. Large discrepancies occur, however, at Ka-band because of the fact that the attenuation-corrected reflectivities are simulated using the snow PSDs that are inferred primarily from the Ku-band reflectivities and R-D_m assumption. The Ka-band reflectivity profiles are merely used as one of the constraint equations in determining R-D_m relations. Large differences between the Ka-band measured and attenuation-corrected reflectivities raise questions as to the validity of the result and any interpretation of snow properties based on the Ka-band corrected reflectivities. Similar concerns can also be raised on the use of the (attenuation-corrected) DFR. For this reason, measured snow reflectivities are used for the DFR-based retrieval.

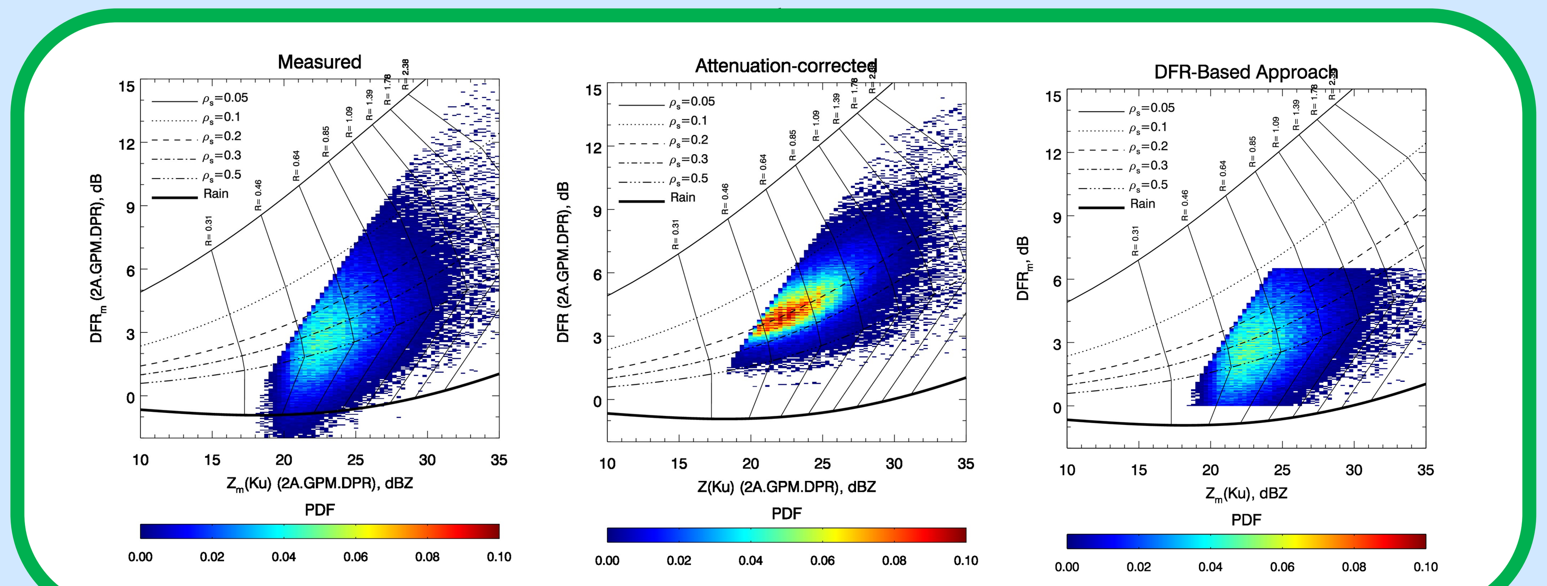

Fig.3 Left: DFR vs. measured Ku-band reflectivity from the DPR standard product 2A.GPM.DPR; Middle: Attenuation-corrected DFR vs. Ku-band reflectivity (2A.GPM.DPR); Right: DFR vs. Z(Ku) derived from the DFR-inferred PSD. Note that the upper limit of Dm is set to 1.5 mm for the DFR-based approach because of the limit of the GSFC and FSU scattering database that have largest liquid-equivalent diameter ~3 mm. As a result, there is a cutoff of DFR in the right plot.

PSD Conversion

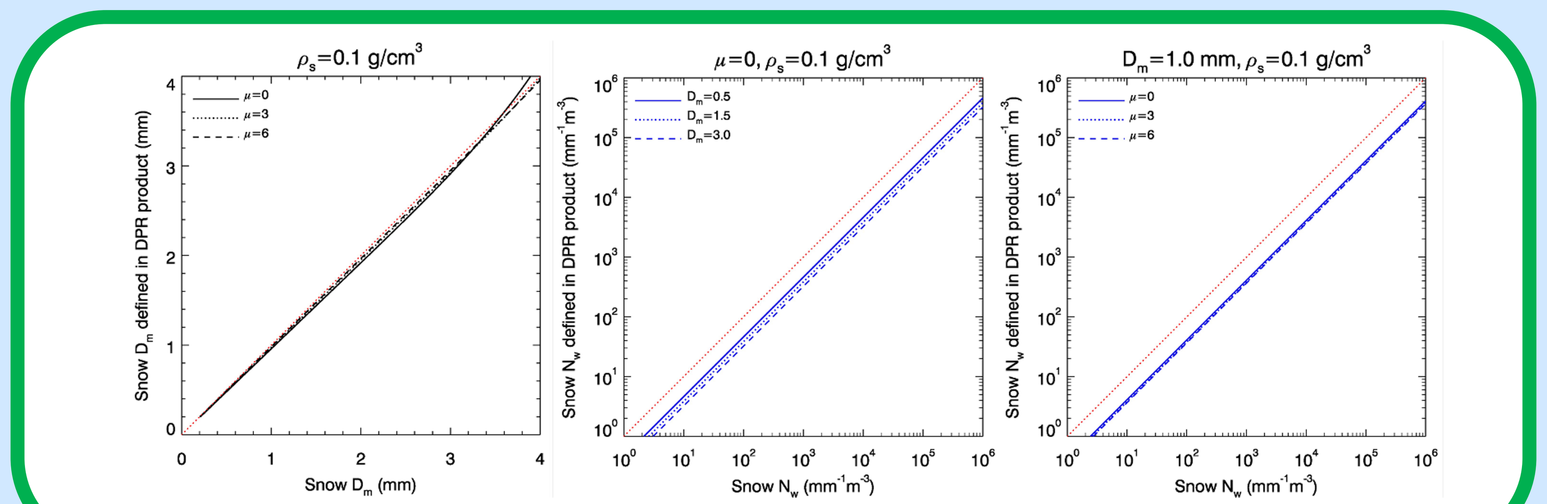

Fig.4 A conversion of PSD derived by the DFR-based approach to the PSD defined in the DPR product is required to compare their estimates of the snow PSD. The N(D), defined in the DPR algorithm, is the rain-equivalent PSD whereas the DFR approach gives $N_S(D)$. To compare the two we use the relationship: $N(D)V(D) = N_s(D)V_s(D)$, where V(D) and $V_S(D)$ are rain and snow fall velocities, respectively. Plotted are relationships between $N_S(D)$ and N(D) in terms of D_m and N_w.

Retrieval Comparisons

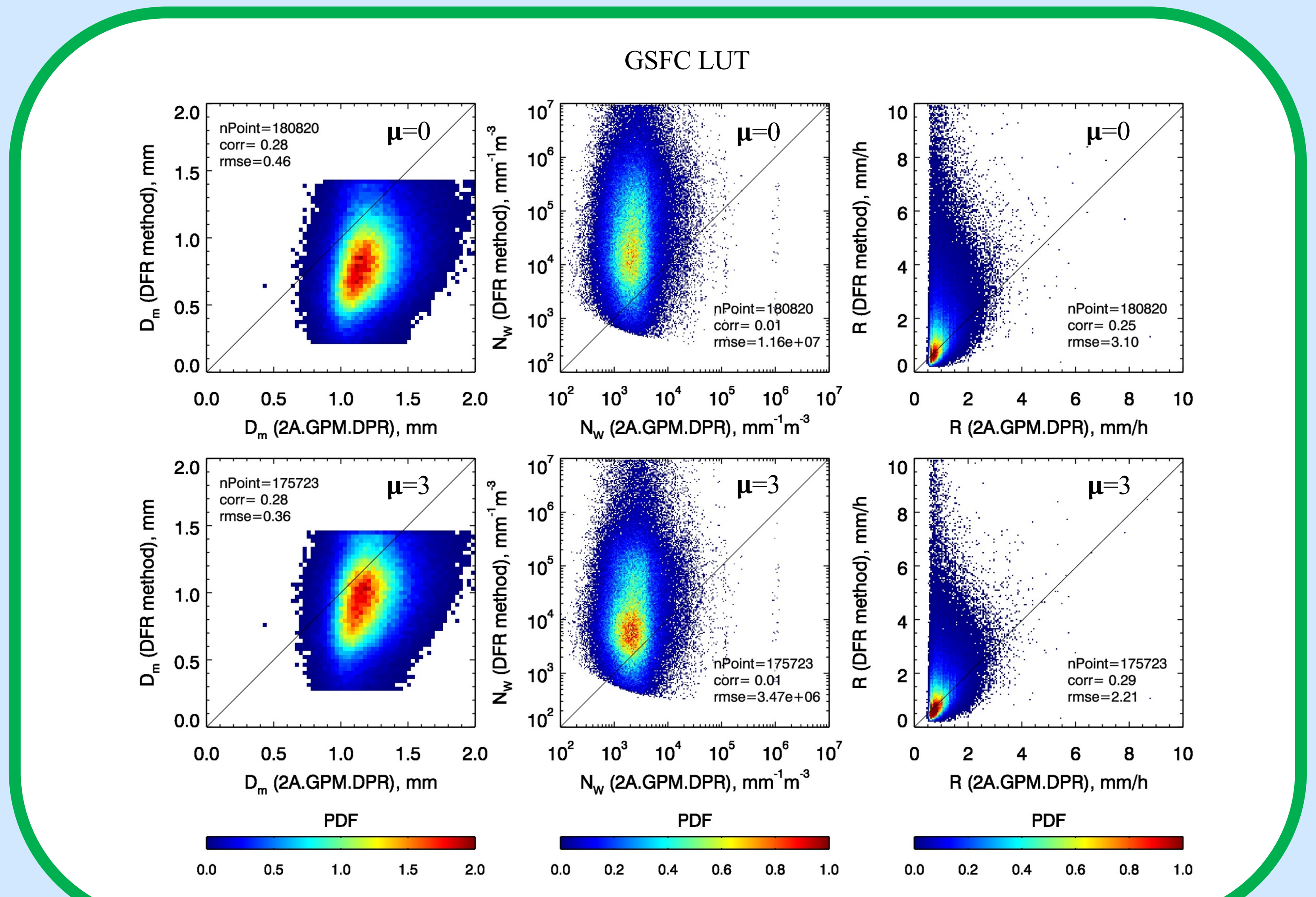

Fig.5 Comparisons of D_m (left column), N_w (middle column) and R (right column) between the DFR-derived and the GPM DPR product as **μ** of the gamma PSD equals to 0 (top row) and 3 (bottom row). GSFC LUT is applied for the retrieval.

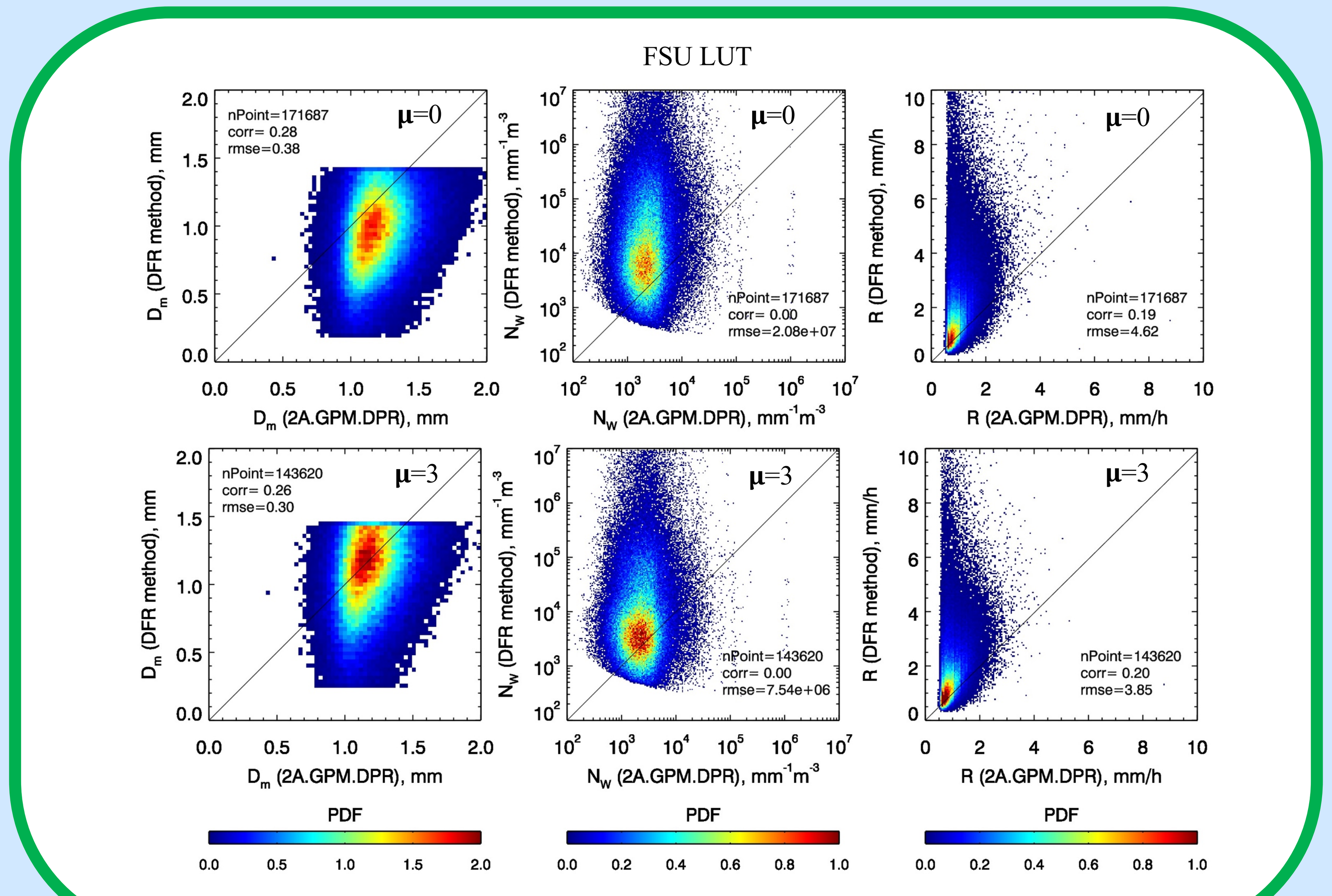

Fig.5 Same as Fig.5 but FSU LUT is applied for the retrieval.

Remarks

- DPR snow estimates deviate to a great degree with the results derived from DFR-based approach.
- Retrievals in snow depend slightly on **μ** values and choice of scattering tables.
- Ka-band attenuation-corrected (or more appropriately called attenuation-free) reflectivities reveal large discrepancies from the measured ones.
- Further study is needed to further examine the DPR snow products.