Vertical Profiling of Precipitation Characteristics for GPM Ground Validation

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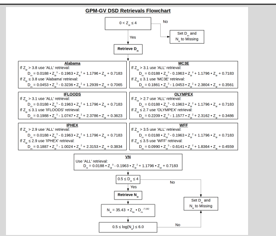
Characterization of the vertical structure/variability of precipitation and resultant microphysics is critical in providing physical validation of space-based precipitation retrievals. In support of NASA's Global Precipitation Measurement (GPM) mission Ground Validation (GV) program, a Precipitation Research Facility (PRF) has been established at NASA Goddard Space Flight Center Wallops Flight Facility (WFF) at Wallops Island, Virginia. The GPM PRF has deployed numerous precipitation measuring instruments including rain gauges, disdrometers, profilers and ground-based radars, including NASA's dual-polarization (NPOL) S-band radar.

Utilizing a large database of disdrometer observations taken during numerous GPM field campaigns, and longer term observations from the University of Alabama – Huntsville (UAH) and Wallops Flight Facility, retrievals of key drop size distribution parameters (D_M, mass-weighted drop diameter; and N_W, intercept parameter) were derived for use with polarimetric radar observations from NPOL. Figure 1 shows how these retrievals are obtained from a combination of differential reflectivity (Z_{DR}) and reflectivity (Z_H) observations.



When weather is present, NPOL runs in a set mode by performing a 360° Plan Position Indicator (PPI) followed by a series of Range Height Intervals (RHI) over WFF and over a high-density gauge network centered over Pocomoke City, MD. This series of scans is repeated every three minutes. In this study, we use the RHI data over WFF over the range interval 35-40 km to simulate the nominal resolution of the GPM DPR of 5 km at nadir to investigate the characteristics of three measured fields (Z_H, Z_{DR} and K_{DP}) and three retrievals (rain rate (RP), D_M and N_W).

In this study, stratiform/convective rain events were manually identified by inspecting RHI scans taken by NPOL. Future efforts will employ a more objective classification. That being said, the various stratiform/convective profiles were sub-set from the overall database and then bulk statistics were produced from both rain type collections. Table 1 provides the dates and times of the various precipitation events.

The total number of convective profiles was 1882. The total number of stratiform profiles was 2061, so there is a fairly even number of profiles in each class available for comparison. Tropical Storm Bill also effected the NPOL domain on 06/21/2015, but was not included in this study.

Year	Date	Start Time	End Time	Type	Comments
2015	0414	1242	1728	Conv	Isolated w/some strat
2015	0420	0001	0206	Strat	Light shallow
2015	0420	0304	1024	Conv	Shallow increasing vigor
2015	0521	1536	1634	Strat	Widespread
2015	0602	2240	2338	Strat	Widespread w/embedded convection
2015	0621	0000	2400	Strat	TS Bill
2015	0711	1204	1258	Strat	Strong BB
2015	0811	0825	0958	Strat	Convective w/mixed strat
2015	0812	0028	0133	Conv	Intense

Table 1: Dates, times and rain rate types used for this study. The total number of convective profiles was 1882. The total number of stratiform profiles was 2061.

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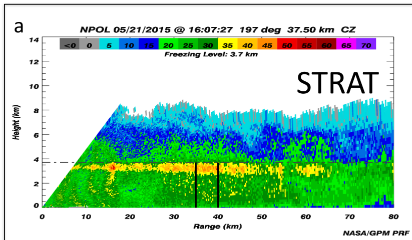
Individual Profiles & Comparisons to Disdrometer Observations

a

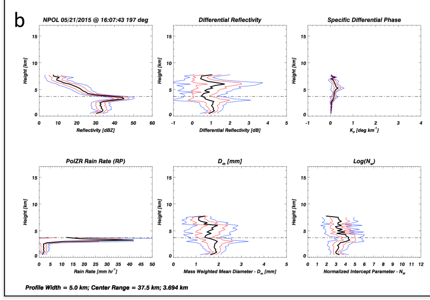


The bright band (BB) below the freezing level (3.7 km) is apparent in the reflectivity field shown in the RHI to the left (Panel a) and quite apparent in the respective reflectivity profile in Panel b. The solid lines in the profile plots is the 5-km horizontal mean, while the red and blue lines represent the +/- 1 and 2 standard deviations, respectively.

Comparison of a single profile shows good agreement between the radar retrieved 1 km value of D_M of about 1.6 mm, and 2DVD-observed D_M (Panel c). The 15-minute mean disdrometer minimum was 1.09 mm, the maximum was 1.91 mm, and the mean was 1.46 mm, with standard deviation of 0.22 mm.

In the profiles, the variance of the Z_{DR} values increases with height, while the variance of rain rates is quite small (note that no rain rates are retrieved above the BB.

b



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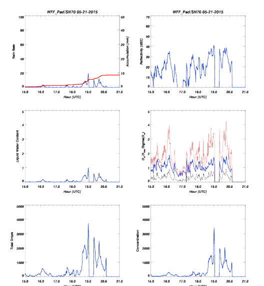

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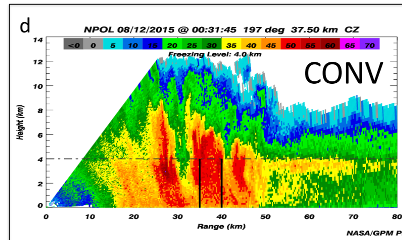


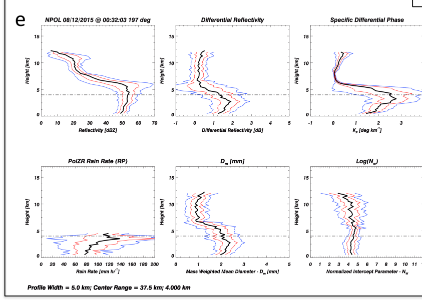
This case shows a strong convective cell over WFF with reflectivities in excess of 55 dBZ, and 5 dBZ echoes extending in excess of 12 km.

Once again, the retrieved 1 km D_M values of approximately 2 mm are well within the 2DVD-observed values: Min =1.78 mm; Max=2.29 mm; Mean=1.97 mm; and a standard deviation of 0.19 mm.

Compared to the stratiform case, the Z_{DR} variances are significantly lower, but the K_{DP} and rain rate means and variances are much higher.

The retrieved NW profile variances are low and the vertical gradient of NW is quite small. The DM profile shows a general increase with height (2-2.5 mm), up to the BB but then a fairly significant decrease between 5-7 km to about 1 mm and remaining near constant to echo top.

e



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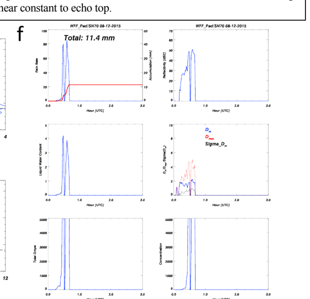


Bulk Statistics – PDF, Scatter and Mean Profiles

Height	ZH	ZDR	KDP	RP	DM	NW
Convective						
1	36.57/9.33	0.35/0.33	0.11/0.27	6.46/14.45	1.12/0.31	4.16/0.33
2	37.04/9.53	0.34/0.34	0.12/0.31	5.98/13.76	1.11/0.33	4.16/0.27
3	37.80/10.12	0.83/0.31	0.18/0.34	6.95/15.05	1.58/0.28	3.84/0.26
4	35.31/9.60	0.61/0.37	0.20/0.42	17.29/25.38	1.26/0.23	3.74/0.51
5	32.77/8.55	0.61/0.38	0.21/0.36		1.23/0.28	3.66/0.58
Stratiform						
1	33.22/9.24	0.45/0.36	0.06/0.09	2.95/4.38	1.19/0.35	3.98/0.41
2	32.89/8.90	0.43/0.33	0.07/0.09	3.00/3.94	1.18/0.33	4.03/0.36
3	34.68/9.52	0.60/0.39	0.10/0.11	4.53/4.43	1.37/0.39	3.96/0.35
4	34.98/11.21	0.54/0.31	0.12/0.14	8.14/7.63	1.25/0.29	3.94/0.41
5	25.07/7.08	0.44/0.43	0.19/0.29		1.12/0.22	3.97/0.54

Table 2: Mean and standard deviations of observed and retrieved parameters derived from 1882 convective profiles and 2061 stratiform profiles.

Table 2 shows the mean and standard deviations of the key parameters investigated in this analysis as a function of height and rain type. Rain rates in convection are nearly twice as high as stratiform rates. D_M values and N_W values between convective and stratiform are mostly similar but the D_M values in both rain types tend to increase in the mid-levels (3-4 km).

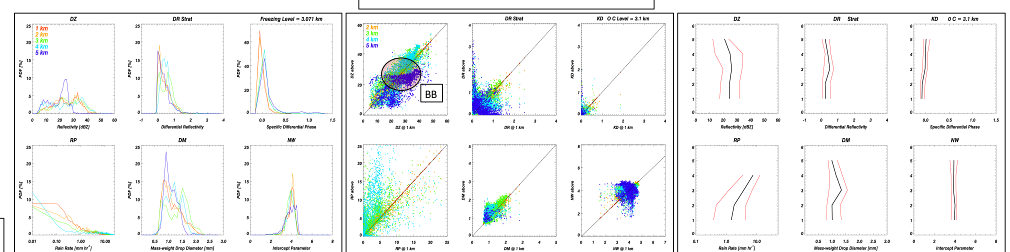
The panels to the right show the PDFs, scatterplots and bulk mean profiles derived from all 2016 stratiform (top) and 1882 convective (bottom) profiles. Looking at the DZ PDFs, a bi-modal distribution of stratiform reflectivity profiles at 5 km is probably associated with the higher BB reflectivity and the lower reflectivities in snow above the BB. These suggested modes are highlighted in the stratiform scatter plot of reflectivity. Note that there is no bi-modal distribution seen in the convective reflectivity PDFs.

The far right panels show the bulk mean profiles. Both the D_M and N_W profiles for stratiform are quite similar, although the convective D_M exhibit a stronger increase in the 3-4 km level than stratiform. The N_W in stratiform is nearly constant, but the vertical gradient of N_W for convective is slightly negative. Given that the ZDR profiles in both rain types are also quite similar, it leads to the conclusion that the differences in the retrieved values are influenced mostly by the varying reflectivity profiles.

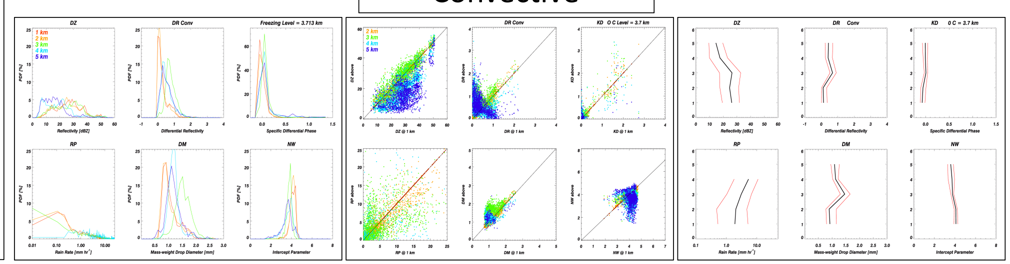
Future Plans

- Use temperature as vertical coordinate in order to normalize the profiles to the melting level height.
- Tie the vertical correlations seen in the scatter plots to horizontal gradients using NPOL PPI data to check for consistency with GPM Validation Network matchups
- Develop a more objective Conv/Strat classification for RHI scans
- Increase database with additional NPOL data
- Use a relational database to develop representative profiles given user-defined characteristics

Stratiform



Convective



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