Evaluation of the GPM DPR Single- and Double-Frequency Algorithms Over the Mediterranean Area

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1. Introduction

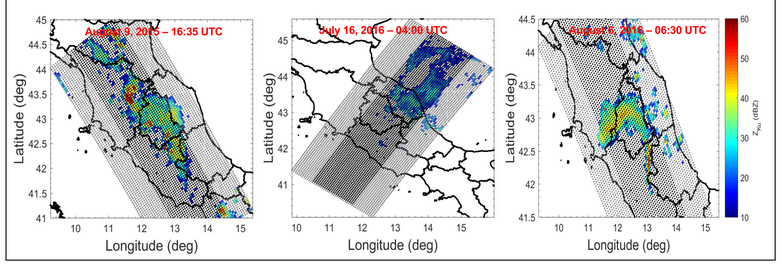
The retrieval of Drop Size Distribution (DSD) and its parameters from Dual-frequency Precipitation Radar (DPR) on board the NASA/JAXA Global Precipitation Measurement (GPM) mission Core Observatory (CO) is one of the key objectives of the whole mission. The GPM mission adopted the three-parameter normalized gamma distribution, which includes the mean mass-weighted drop diameter (D_m), the normalized intercept (N_w), and the shape parameter (fixed at value of 3). The DPR employs three scanning modes: Matched Scan (MS), Normal Scan (NS) and High Sensitivity scan (HS). The Ka- and Ku-band MS footprints of the inner swath consist of 25 angle bins with a vertical resolution of 125 m. While double-frequency (DF) based products are provided for the Ka- and Ku-band radar MS footprints, the Ku-band and Ka-band single-frequency (SF) based products are also provided for the same footprints.

Both SF and DF based DPR algorithms provide DSD and bulk microphysical parameters (e.g., rainfall rate). The present work carries out an intercomparison of the SF and DF DPR products by considering the respective outputs over the Mediterranean area during rain events. The aim is to asses how reliable the SF based estimated DSD parameters are, taking the DF based estimates as reference. A number of DPR related variables have been analyzed: corrected reflectivity ($Z_{ka/Ku}$), Near Surface rainfall rate (R), D_m and N_w. The results show very good agreement between Ku-only and DPR and poorer agreement between Ka-only and DPR. Single- and double-frequency based Z and R are close to each other, while remarkable differences are present for D_m and N_w.

2. Dataset

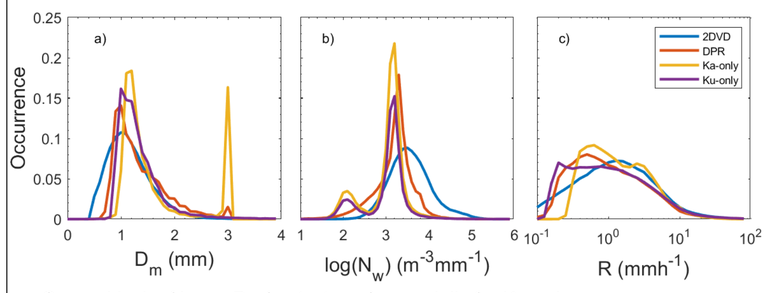
This study uses the observations collected by GPM-CO over Italy between April and October for the 2015-2017 years. More than 150,000 footprints of the inner swath have been analyzed, comparing version 5 (V05) DF 2ADPR-MS product with Ka-only 2AKa-MS and Ku-only 2AKu-NS products.

The figures below show, as an example, three overpasses over Italy among those analyzed and the relative precipitating systems as measured Ku-band radar. The grey dots identify the DPR full swath (NS), while the black dots identify the DPR inner swath (MS).



3. Comparison of GPM products with ground reference

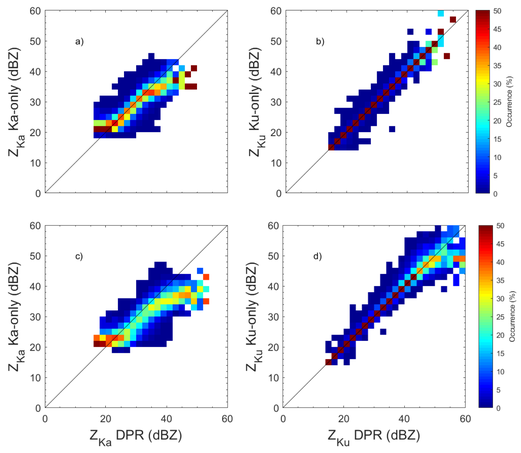
The GPM-retrieved DSD parameters (i.e. D_m, N_w) and R are compared with disdrometer-based DSD parameters. The disdrometer data have been collected by 2DVD at mid-latitude during GPM Ground Validation (GV) field campaigns. The GPM products refer to the Near Surface outputs (i.e. the lowest bin free from ground clutter) for DF (DPR) and SF (Ku-only and Ka-only) products. The figure shows the probability distribution of a) D_m, b) N_w and c) R.



- General lack of lower D_m (up to 1 mm) especially for Ka-only.
- Second peak for DPR and Ka-only at D_m=3 mm related to an overestimation of the Path Integrated Attenuation (PIA).
- Narrow distribution of DF based (DPR) log(N_w), centered around 3.2 $m^{-3}mm^{-1}$, with respect to 2DVD.
- Better agreement between DF-based and 2DVD for R, especially at moderate/heavy rainfall intensity.

4. Single- vs Double-Frequency reflectivity

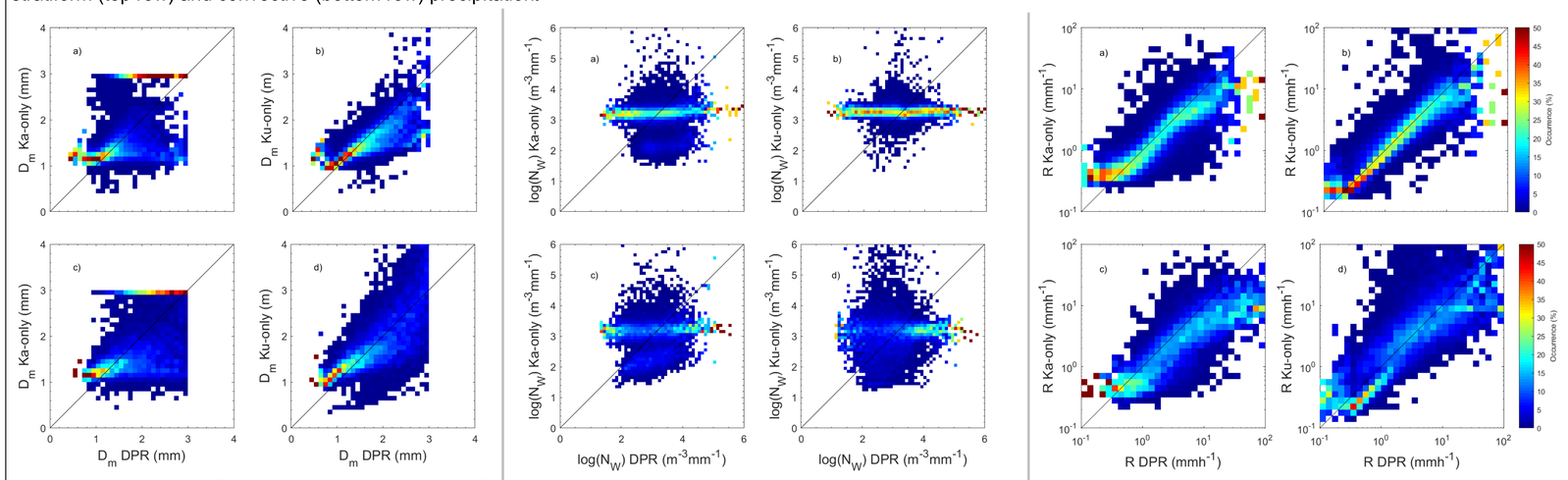
The figures below show the two dimensional density plot of the SF (Ku-only/Ka-only) vs. DF (DPR) corrected reflectivity for Ku-band and Ka-band over land for stratiform (top row) and convective (bottom row) precipitation.



- Very good agreement between DF and SF Z_{Ku} for both stratiform and convective precipitation.
- Good agreement between DF and SF Z_{Ka} for Z<35 dBZ (especially for stratiform precipitation).
- Larger spread for Z_{ka} than Z_{ku}.

5. Single- vs Double-Frequency DSD parameters

Two dimensional density plots of the SF (Ku-only/Ka-only) vs. DF (DPR) DSD parameters, D_m (left column) and N_w (middle column), and rain rate R (right column) over land for stratiform (top row) and convective (bottom row) precipitation.



- Clear evidence of D_m saturation for Ka-only at 3 mm.
- Agreement is better for Ku band than Ka band.
- Both Ku-band and Ka-band SF based log(N_W) estimates are mostly around 3.2 $m^{-3}mm^{-1}$ regardless the log(N_W) DPR values.
- The agreement is good for stratiform precipitation.
- For convective precipitation, Ku-only and Ka-only based R is generally lower than DPR based R, especially at lower intensity .

6. Statistical scores

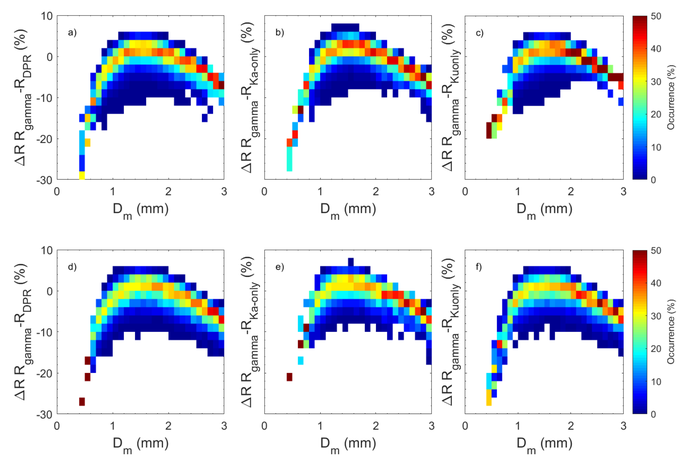
The difference between the considered parameters as estimated by SF and DF based algorithms can be quantified by some statistical score, namely Mean Error (ME), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), considering the DF based products as reference.

		Stratiform							
		Z (dBZ)		D_m (mm)		Log(N_w) ($m^{-3}mm^{-1}$)		R (mmh^{-1})	
		Ka	Ku	Ka	Ku	Ka	Ku	Ka	Ku
ME	Land	-0.62	0.01	0.16	-0.01	-0.20	-0.01	-0.26	0.11
	Sea	-0.41	0.00	0.13	0.00	-0.16	-0.04	0.00	-0.03
MAE	Land	1.76	0.13	0.34	0.13	0.45	0.31	0.85	0.68
	Sea	1.90	0.12	0.31	0.12	0.40	0.30	1.13	0.64
RMSE	Land	2.34	0.47	0.54	0.19	0.61	0.43	2.38	3.40
	Sea	2.53	0.47	0.51	0.18	0.56	0.41	5.11	3.80
		Convective							
		Z (dBZ)		D_m (mm)		Log(N_w) ($m^{-3}mm^{-1}$)		R (mmh^{-1})	
		Ka	Ku	Ka	Ku	Ka	Ku	Ka	Ku
ME	Land	-2.77	0.26	-0.09	0.07	-0.08	-0.04	-3.42	1.62
	Sea	-2.61	0.22	-0.02	0.01	-0.13	-0.01	-7.35	-1.24
MAE	Land	3.42	0.76	0.53	0.40	0.62	0.69	4.43	5.89
	Sea	3.58	0.90	0.55	0.31	0.65	0.60	9.43	7.94
RMSE	Land	4.27	1.71	0.69	0.57	0.76	0.88	14.30	20.14
	Sea	4.58	1.98	0.71	0.45	0.78	0.75	30.38	27.57

- ME is generally negative for Ka-band, close to zero for Ku-band.
- MAE is generally higher over land for stratiform precipitation, while it is higher over sea for convective precipitation for both Ka- and Ku-band.
- RMSE shows more marked difference between land and sea during convective precipitation at both frequencies.

7. Gamma distribution analysis

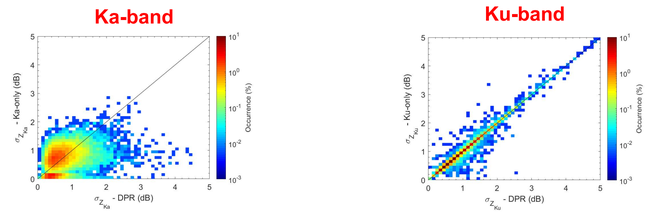
The rainfall rate is derived from the reconstructed DSD (i.e. D_m and N_w and the Gamma shape parameter set to 3) and compared with the SF-based and DF-based rain rate R. The figure below shows the relative error between the Gamma-based R and GPM-based (DPR, Ka-only and Ku-only) R as a function of estimated D_m for stratiform (top row) and convective (bottom row) precipitation over land.



Generally, for D_m < 1 mm and D_m > 2 mm, the Gamma-based R estimates are lower than GPM-based R products, while the opposite holds for D_m between 1 and 2 mm. The relative error is generally between -5% and +5%, while at lower end of D_m the error can be as low as -15%. These features are evident for DPR, Ku-only and Ka-only.

8. Vertical analysis

The variability of Z and DSD parameter profiles has been analyzed for those cases where the bright band (BB) was present. The bins between the BB level and the first bin free from ground clutter have been analyzed. The figure below reports the standard deviation (σ) of the DF (DPR) and SF (Ka-/Ku-only) based reflectivity for stratiform precipitation over land.



- DF and SF based σ_{ZKu} have most of the points on the one-to-one line.
- The spread of distribution of DF and SF based σ_{ZKa} is more marked than Ku even if the range of σ_{ZKa} is lower than σ_{ZKu} for both DF and SF based Z.

9. Conclusions

- There is a good agreement between the SF-based and DF-based reflectivity corrected for attenuation.
- The SF-based and DF-based DSD D_m estimates are in good agreement, even if there is a significant spread. The agreement becomes worse for N_w and improves for R.
- The statistical scores show a better agreement between DF and Ku-only than between DF and Ka-only. The performances are better during stratiform than convective precipitation, with similar results over land and sea.
- The relative error between the Gamma-based R estimates and the GPM-based R is generally low regardless the D_m value (better performances are obtained for D_m between 1 mm and 2 mm).
- The analysis of the vertical profiles of the analyzed parameters shows a small difference between the SF and DF based estimates.

Acknowledgments

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