Comparing GPM Satellite to Ground Platform Measurements: Case Studies from the NASA GPM Wallops Precipitation Science Research Facility

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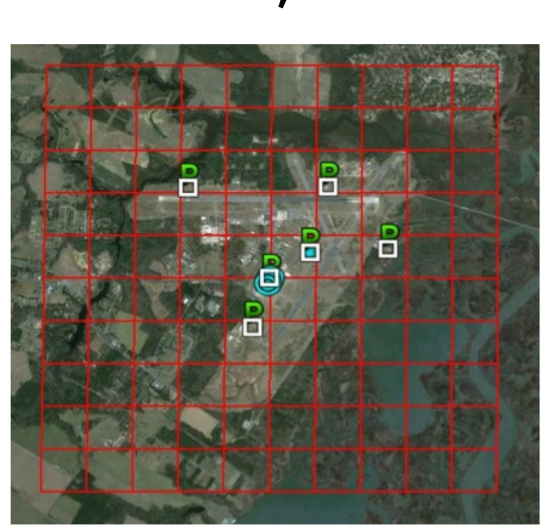
Introduction & Motivation

- NASA's Global Precipitation Measurement (GPM) mission continues to evolve with improvements in rain drop size distribution (DSD) and rainfall algorithms
- Given uncertainty in the DSD estimates and thus rainfall over a GPM-Dual Precipitation Radar footprint (Tokay et al. 2016), a robust ground validation analysis is crucial to understand the limitations of space based measurements and provide for improvements
- A case study of two different rainfall GPM overpass events are analyzed from the GPM Ground Validation (GV) Precipitation Research Facility (PRF) at NASA Wallops Flight Facility (WFF) utilizing research quality polarimetric Doppler radars, disdrometers, and rain gauges
- The goal of this study is to identify possible mismatches between GPM footprint estimates and GV measurements

Data & Observations

Precipitation measuring platforms include NASA's S-band Dual-Polarimetric Radar (NPOL), Ka/Ku-band Dual-Polarization Dual-frequency Doppler Radar (D3R), K-band Micro Rain Radar (MRR), NOAA's S-band Weather Surveillance Radars 1988 Doppler (WSR-88D), GPM multi-channel Microwave Imager (GMI) and Ka/Ku-band Dual-frequency Precipitation Radar (DPR), 2-Dimensional Video Disdrometer (2DVD), Particle Size and Velocity (PARSIVEL) disdrometer, and dual tipping rain gauges.

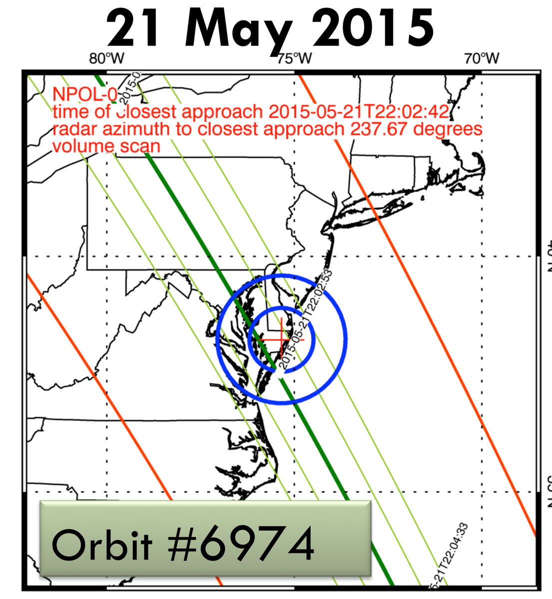


- White boxes = 2DVDs
- Green P symbols = PARSIVEL disdrometers

Two Case Studies

Two GPM short distance (< 60 km from nadir track) overpass events over the Wallops Flight Facility are considered for this study:

21 May 2015



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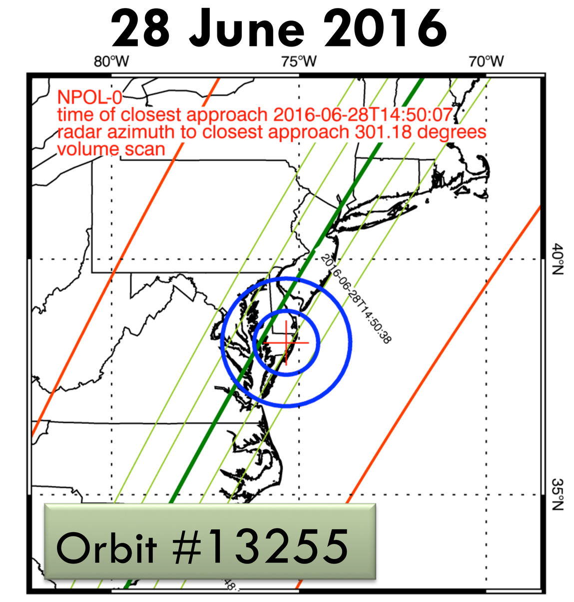


Analysis Set-Up

The System for Integrating Multi-platform data to Build the Atmospheric column (SIMBA – see Wingo et al. 2017 poster #112) framework is used to ingest precipitation measuring platform data into an atmospheric column product.

Define Column Grid
-Center location WFFPAD
-Vertical & horizontal Extent: 5 x 5 x 5 km
- Grid spacing: 500 m

↓

Select Data
-Radars, disdrometers, gauges, GPM

↓

Output netCDF File
-Column 3D gridded data

↓

Compute Statistics
-Average (at each layer in column)
-Bias error

$$bias = \frac{satellite - gv}{gv}$$

Algorithms

1. Rain rate, R (mm hr^{-1})
2. Mass-weighted mean diameter, Dm (mm)
3. Normalized intercept parameter, Nw ($mm^{-1}m^3$)

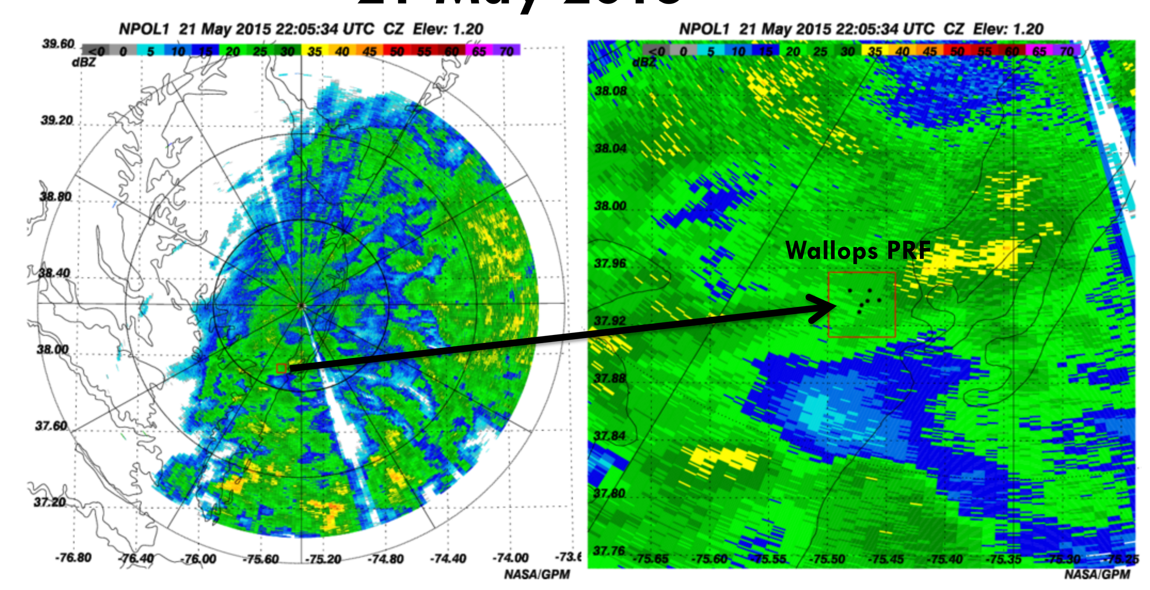
i. Rain rate estimated from GV radars (NPOL, KDOX, KAKQ) uses the DROPS2.0 algorithm (Chen et al. 2017) while GPM-DPR uses the newly R-D_m relation (Kozu et al. 2009, Seto et al. 2016). GPM-GMI uses the GPROF algorithm (Kummerow et al. 1996, 2015) to estimate rainfall.

ii. The drop-size distribution variables (Nw and Dm) from GV radars are estimated using dual-polarization variables following Gorgucci et al. (2002) and Bringi et al. (2004) methods following a DSD retrieval flow chart (Tokay et al. 2017 – manuscript in process for submission). The DSD variables estimated from GPM DPR rely on the Ka and Ku reflectivity measurements (Seto et al. 2013).

- Satellite refers to GPM (GMI or DPR) while gv refers to ground scanning/profiling radars, disdrometer, gauges, and APUs.
- Timestamps of input data ranged from -180 to +180 and -200 to 200 seconds of NPOL scan time (05/21-22:04:20) and (06/28-14:49:47)

Results & Analysis

21 May 2015



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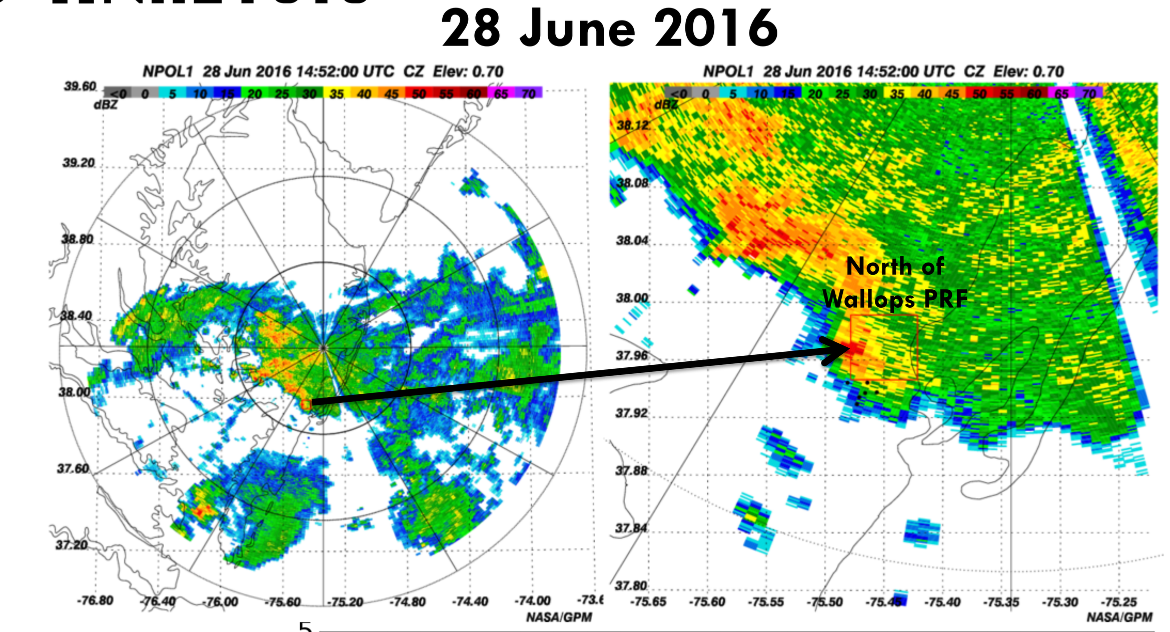
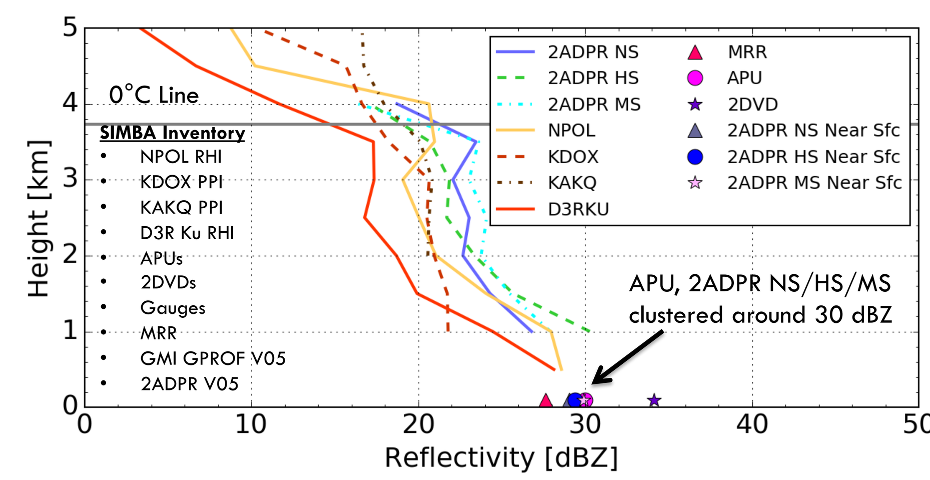
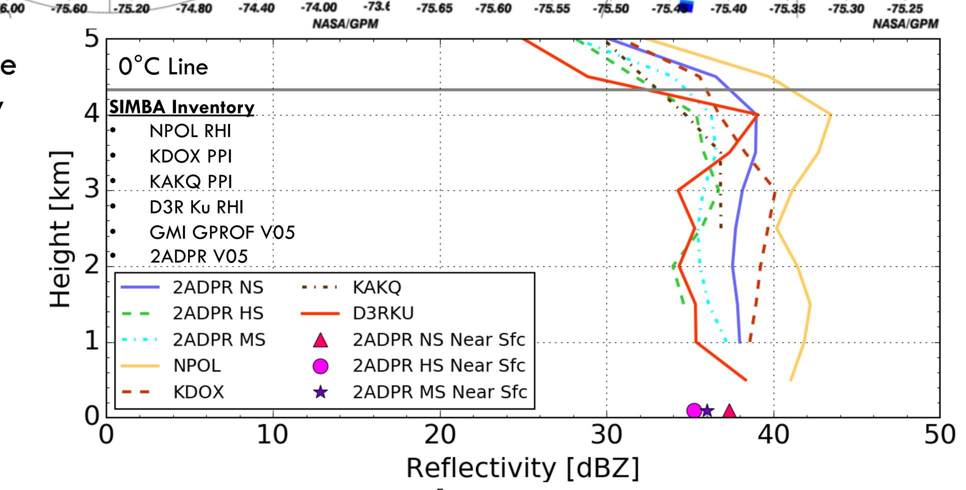
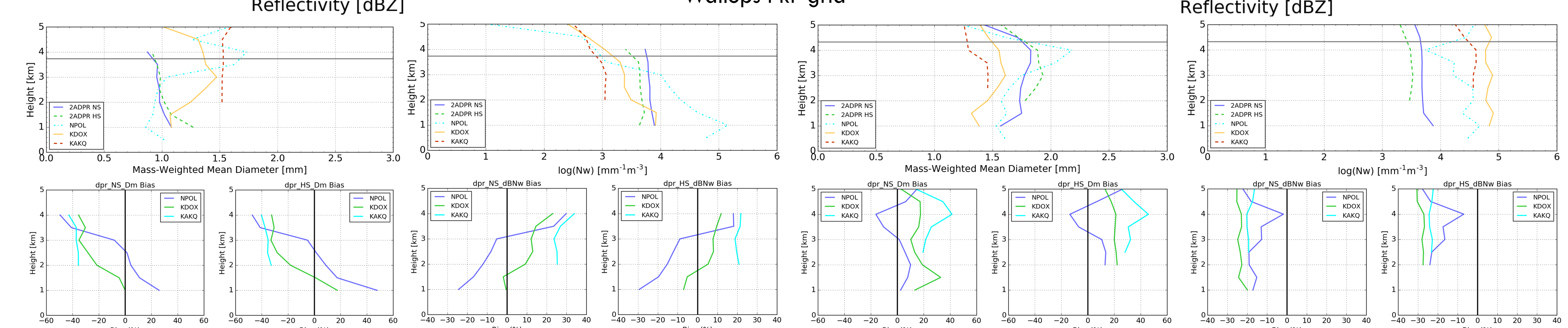




- Note S-band reflectivities are not adjusted to Ku frequency for comparison
- Distance from Wallops PRF:
  - NPOL – 38 km
  - KDOX – 98 km
  - KAKQ – 170 km
  - D3R, disdrometers, gauges all within the Wallops PRF grid



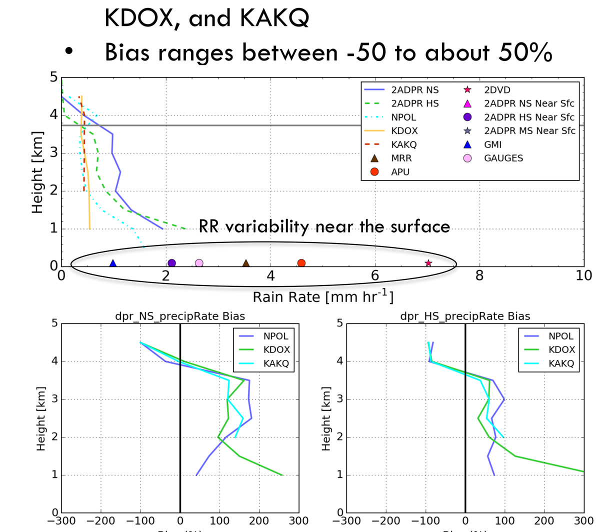


- Dm has values between 0.7 and 1.6 mm in the column
- GPM 2ADPR algorithm has an increasingly negative bias with height relative to NPOL, KDOX, and KAKQ
- Bias ranges between -50 to about 50%

- Nw in log space has values between 1.0 and 5.0 $mm^{-1}m^3$
- GPM 2ADPR has an increasingly positive bias with height
- Bias is between -30 and 30%

- Dm has values between 1.3 and 2.2 mm
- GPM 2ADPR is slightly positively biased, especially relative to 88D's which are further away than NPOL
- Bias is in the range of -20 to 20%

- Nw has values between 3.5 and 5.0 $mm^{-1}m^3$
- GPM 2ADPR NS has a bias around -20%
- GPM 2ADPR HS has a bias in the range of -30 to -20%



- Rain rate (mm hr^{-1}) profiles show some variability, especially near the surface
- GPM 2ADPR algorithm has an increasingly negative bias with height

Bias Error % (Rain Rate Near Surface Algorithm)

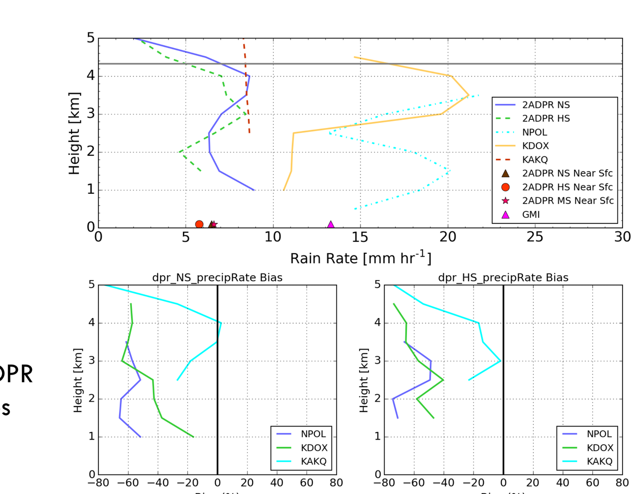
2015_0521	MRR	APU	GAUGES	2DVD	GMI
GMI	-85.3	-78.5	-62.5	-85.9	X
2ADPR NS	-60.6	-42.6	0.23	-62.4	167.2
2ADPR HS	-68.5	-54.1	-19.9	-70.0	113.6
2ADPR MS	-60.6	-42.6	0.23	-62.4	167.2

2016-0628	GMI
GMI	X
2ADPR NS	-51.2
2ADPR HS	-56.7
2ADPR MS	-50.4

- Near-Surface GPM 2ADPR algorithms agree well with the gauges compared to the other platforms
- 2ADPR overestimates relative to GMI GPROF algorithm
- GPM GMI GPROF underestimates rainfall near the surface compared to APU, gauges, and 2DVD

- Near-Surface GPM 2ADPR algorithm underestimates relative to GMI GPROF algorithm

For more examples of SIMBA applications, see poster #112: Applying the SIMBA Data Fusion Framework to OLYMPEX: Multi-Platform Observational Analysis of an Intensively Sampled Orographically Enhanced Precipitation Event – Wingo et al. 2017)



- Rain rate (mm hr^{-1}) profiles show decent variability in the column
- GPM 2ADPR bias relative to GV is between 0 to -80% and underestimates relative to GV radars

Conclusions

a) GPM 2ADPR rain rate has a larger bias in the stratiform event compared to the convective event
b) GPM 2ADPR overestimates rainfall relative to GMI in the stratiform event and underestimates in the convective event
c) Near surface rain rate algorithm for DPR had the lowest bias when compared to gauges in the stratiform rain event
d) GPM 2ADPR Dm had an increasingly negative bias relative to GV radars in the stratiform event while bias was between -20 and 20 % for convective case
e) GPM 2ADPR Nw had an increasingly positive bias in the stratiform event while stayed relatively constant in the convective event with height
f) The cause of the biases can be a number of reasons: differing distance/height of GV radar sites, data resolution (PPI vs RHI), beam filling errors, and gridding/interpolation artifact
g) Robust agreement between GPM and GV is difficult to obtain on a case by case basis thus need lots of case analysis to draw concrete conclusions on uncertainties

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