Ground Validation Assessments of GPM Core Observatory Science Requirements

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- **"Level-1" Science Requirements**
- **Data**
- **Rain rate**
- **DSD**
- **Demonstrating Snow Detection**
- **Summary**

GPM "Core" Satellite Science Requirements

(Termed "Level -1" or "L1")

- DPR: *quantify rain rates* between 0.22 and 110 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 5 km*.

- GMI: *quantify rain rates* between 0.22 and 60 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 15 km*.

- Core observatory radar estimation of the Drop Size Distribution (DSD)- specifically, D_m *to within +/- 0.5 mm*.

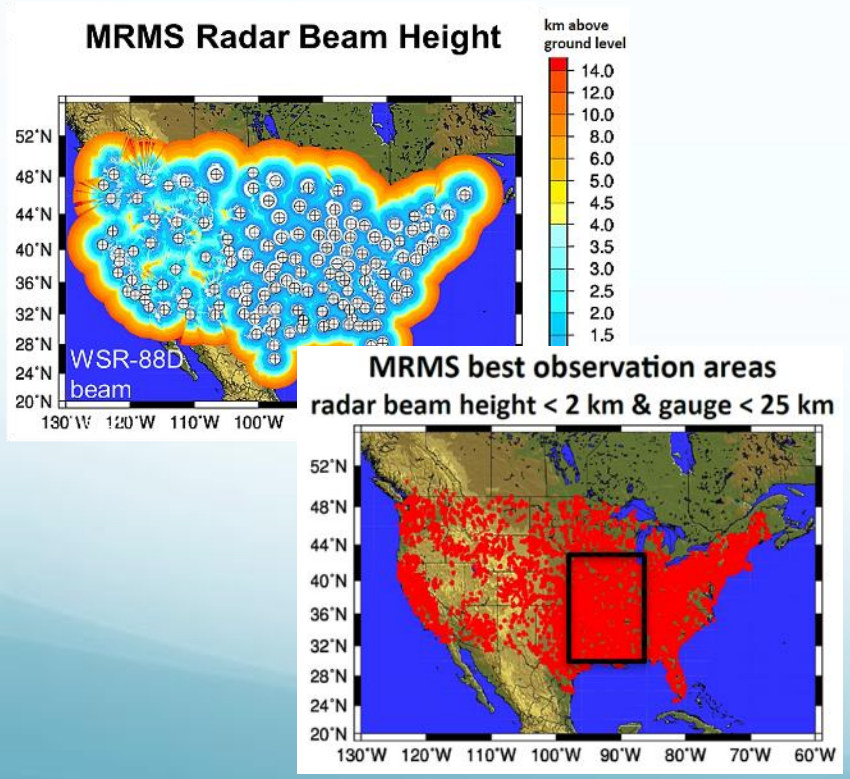
- Core observatory *instantaneous* rain rate estimates at a resolution of 50 km with *bias and random error* $< 50\%$ *at 1 mm* hr^{-1} *and* $< 25\%$ *at 10 mm* hr^{-1}, *relative to GV*

Data

http://gpm-gv.gsfc.nasa.gov/

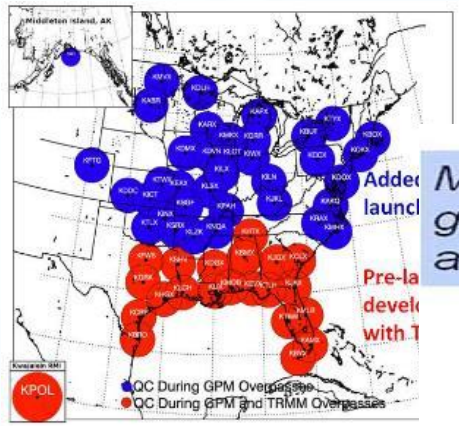
1) NOAA Multi-Radar Multi-Sensor (MRMS) Precipitation Rates

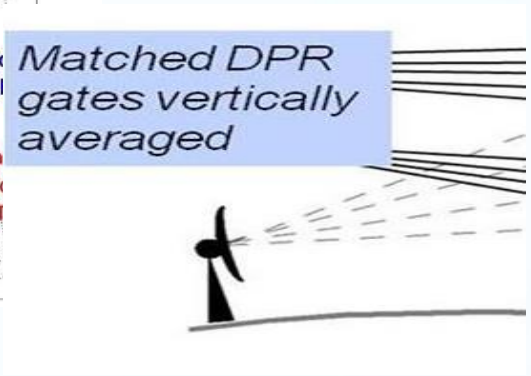
- Gauge bias-corrected radar estimates of precip ***rate and type***
- 0.01º / 2 minute resolution
- Quality-constrained "reference" subsets created



2) Validation Network

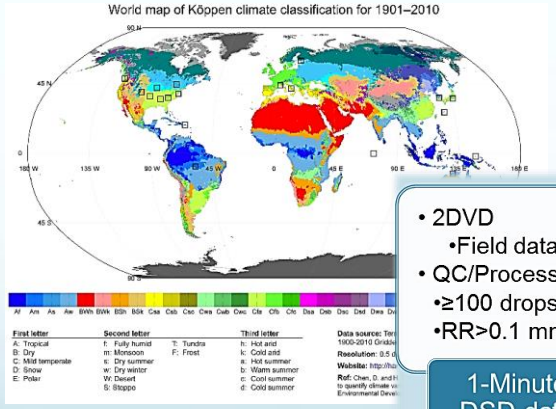
- QC'd 3-D radar volumes and variables geo-matched to DPR sample volumes and GMI footprints
- 65 US + numerous research and international radars

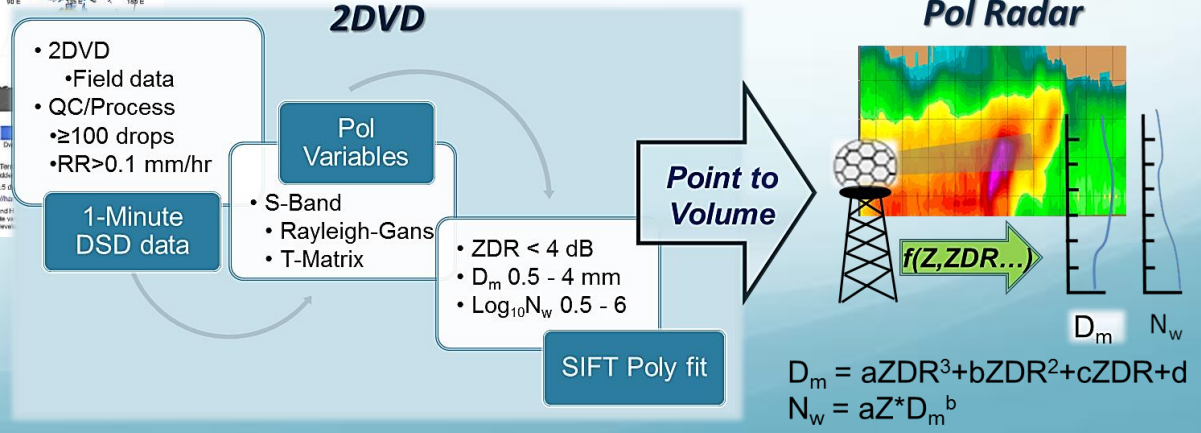




3) Field campaign and Extended Site observations

- Disdrometer sites/network datasets from GPM GV and partners

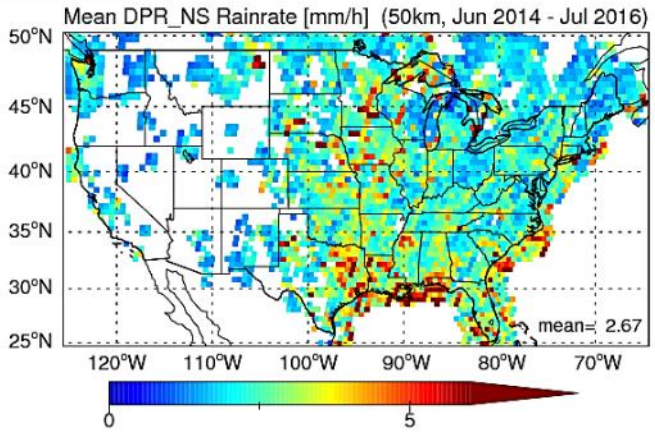




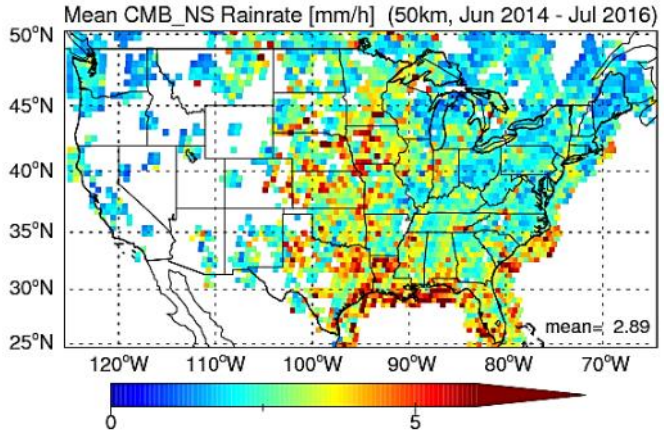
Rain: General Behavior for Version 5 L1 (50 x 50 km)

CONUS Mar 14 – July 16: GV MRMS vs. DPR, Combined, and GMI GPROF **V5**
Conditioned on 0.2 mm/hr threshold at FOV

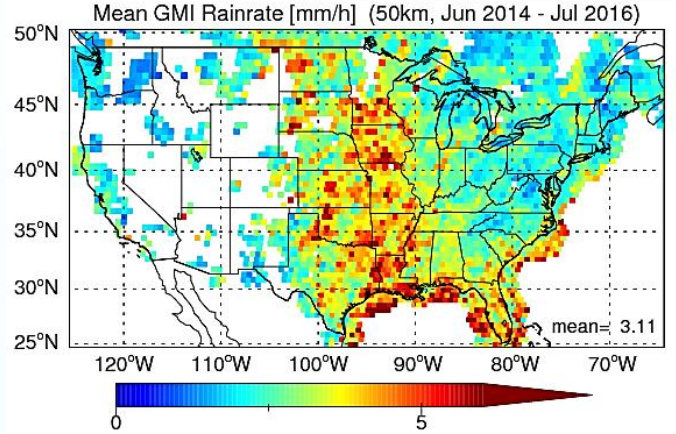
DPR



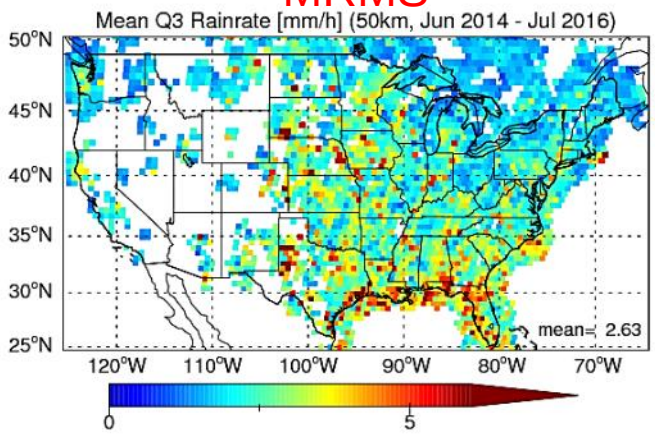
Combined



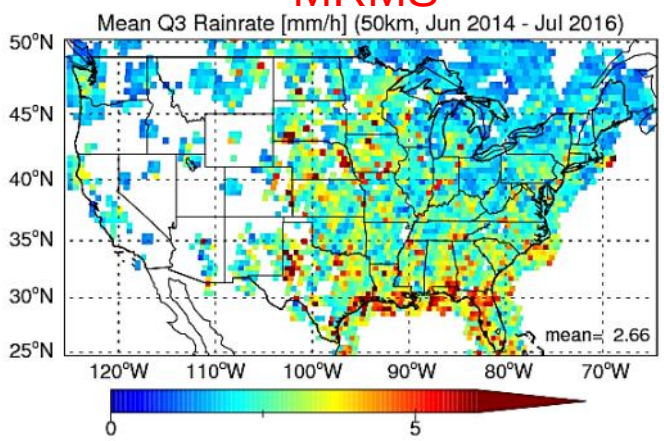
GPROF GMI



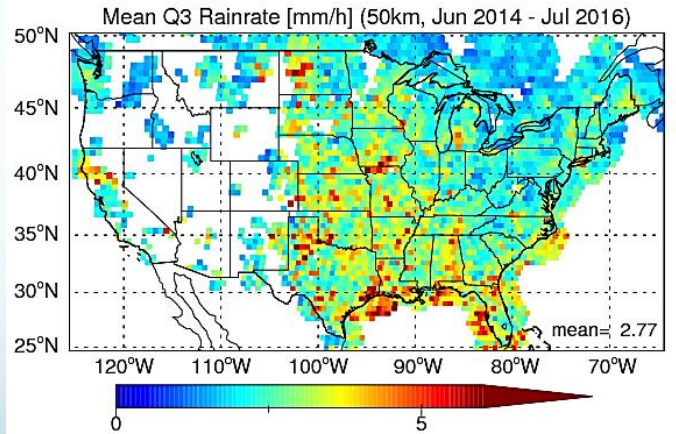
MRMS



MRMS



MRMS



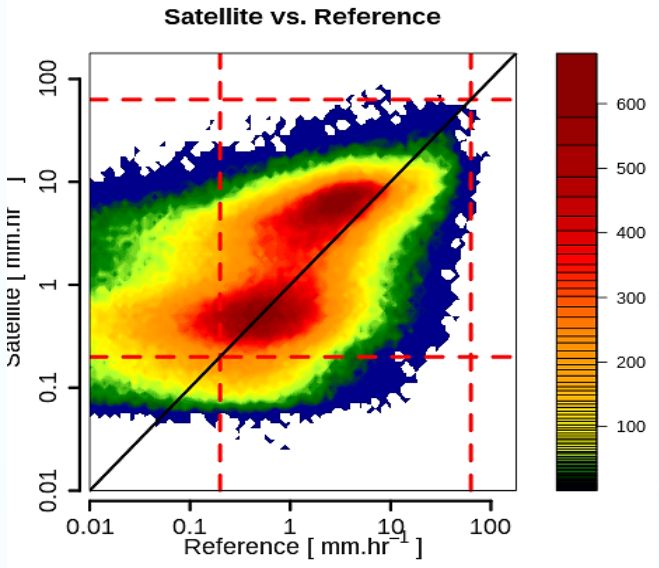
- Radar-based products in better agreement with MRMS; GPROF estimate in "MCS alley" still a little high.

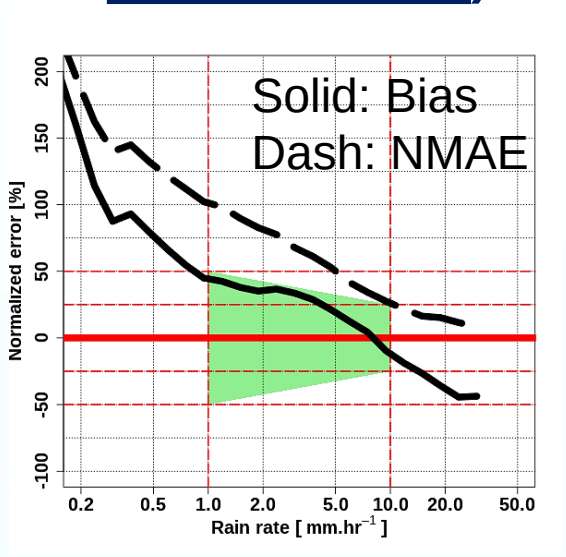
Versions 4 and 5 GPROF GMI **Rain Rate** vs. GV MRMS

EFOV "Footprint" (15 km)

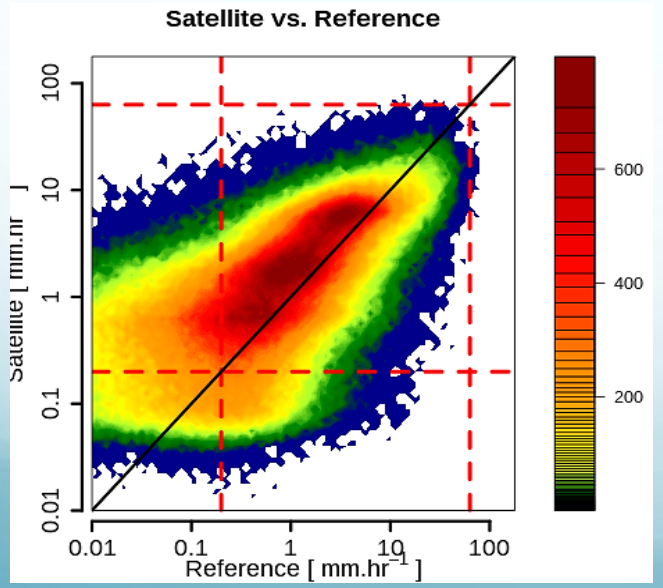
Level 1 (50 km)

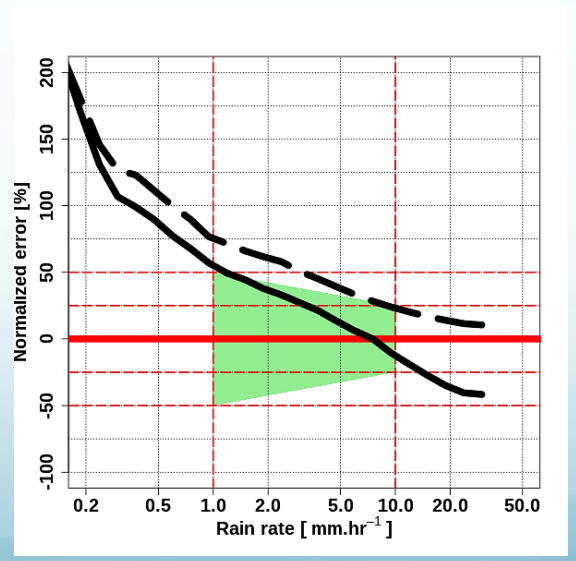
V4





V5





V4

Footprint:

Correlation 0.47, bias 24.6%- non-uniform and with modes;

L1:

Footprint:

- Range of 0.2 - 60 mm/hr ✓
- 50 x 50 km ✓
- Bias
- Random error (NMAE) X

V5

Footprint:

Correlation 0.57, bias 20 %;

Smoother bias, reduced NMAE; greater extension to light rain;

L1:

Footprint:

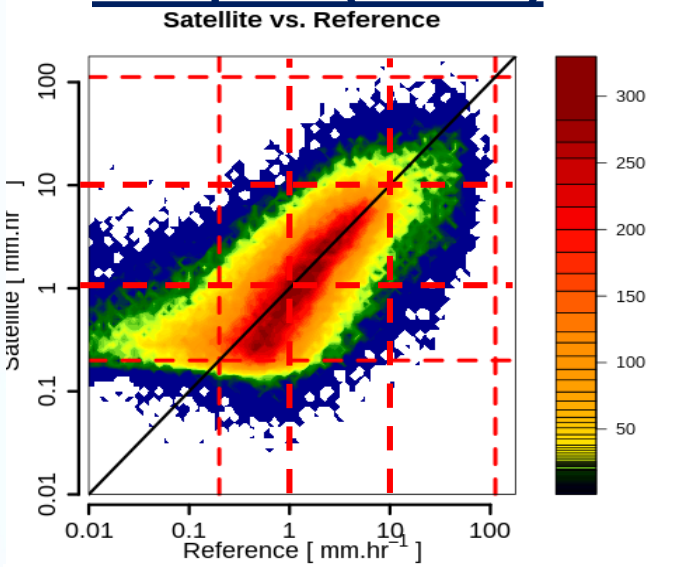
50x50km

- Bias: (better) ✓
- NMAE: (still a bit high) X

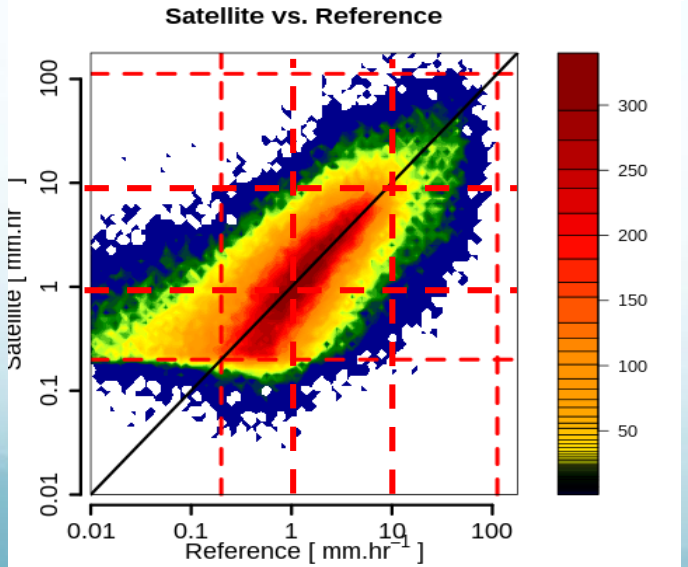
V4 and V5 **DPR MS**, and L1 **Rain Rate** vs. GV MRMS

Footprint (~ 5 km)

V4

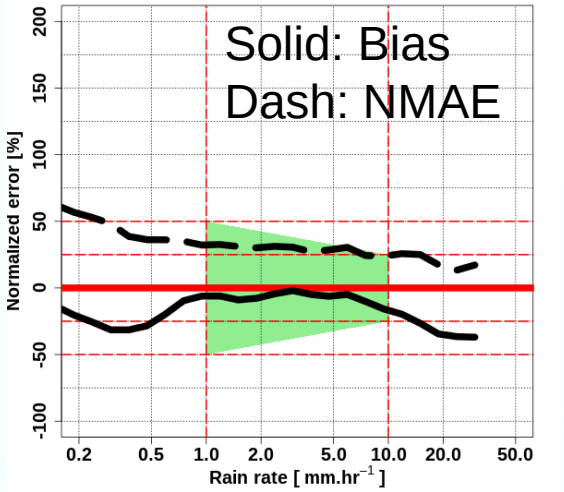


V5

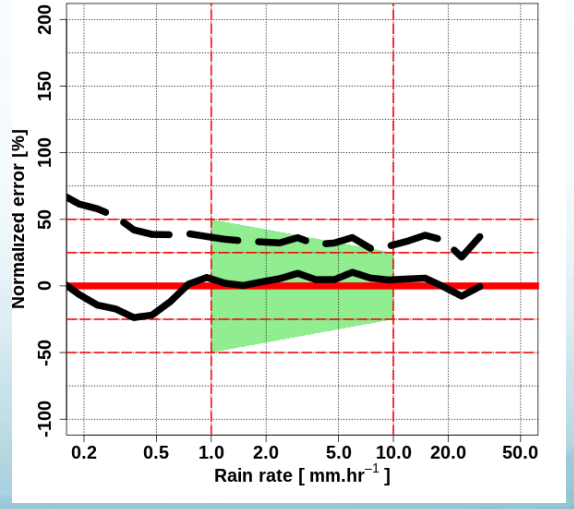


Level 1 (50 km)

V4



V5



V4 ok, V5 better!

- V5 Conditional bias < 12%

<u>L1:</u>

Footprint:

0.2-110* mm/hr

(*sample numbers at >100 mm/hr; < 0.01%)

50 x 50 km

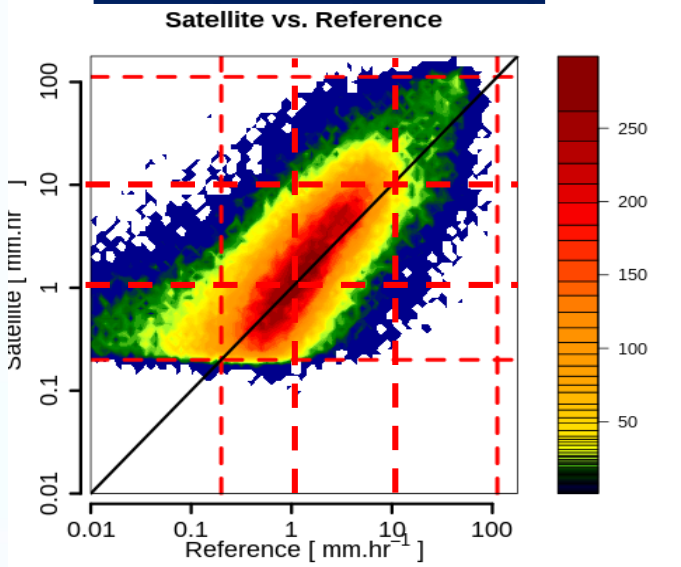
Bias

NMAE (improved V5)

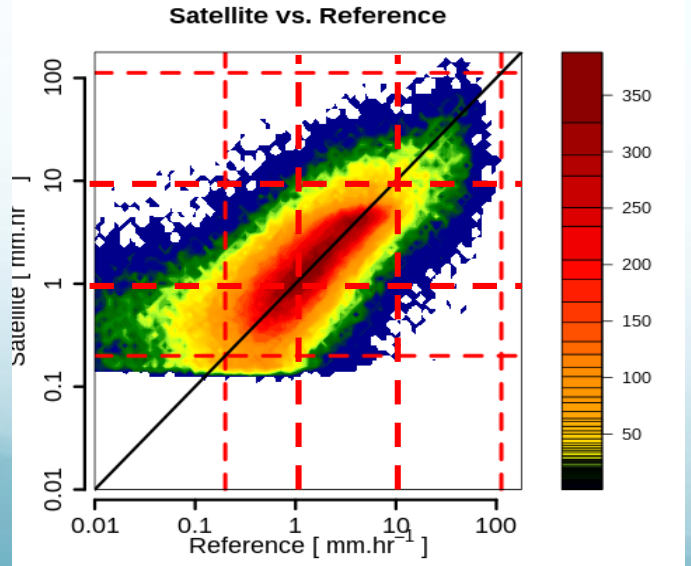
V4 and V5 **Combined Alg. MS**: **Rain Rate** vs. GV MRMS

Footprint (~ 5 km)

V4

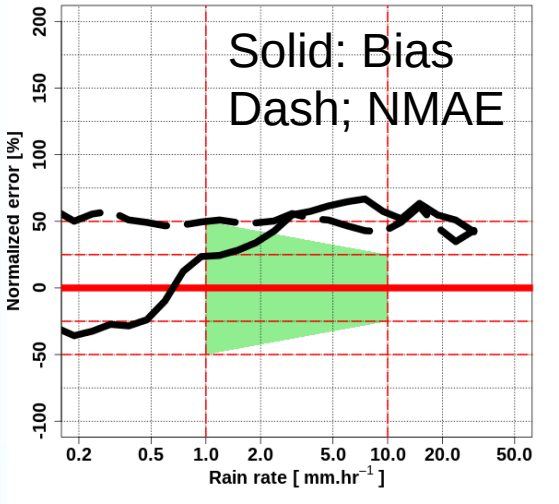


V5

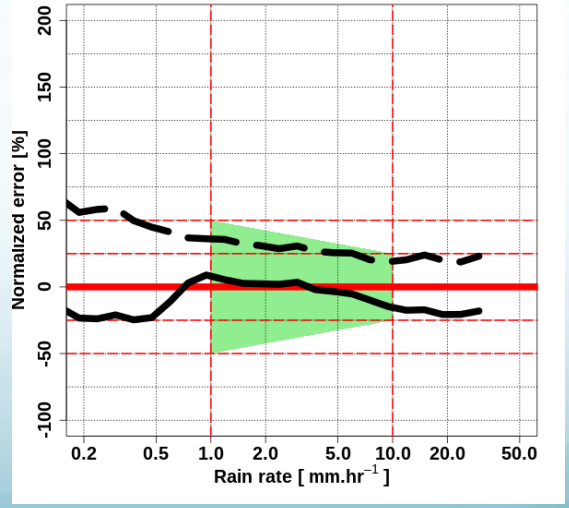


Level 1 (50 km)

V4



V5



Relative to V4, V5 is **MUCH** improved!

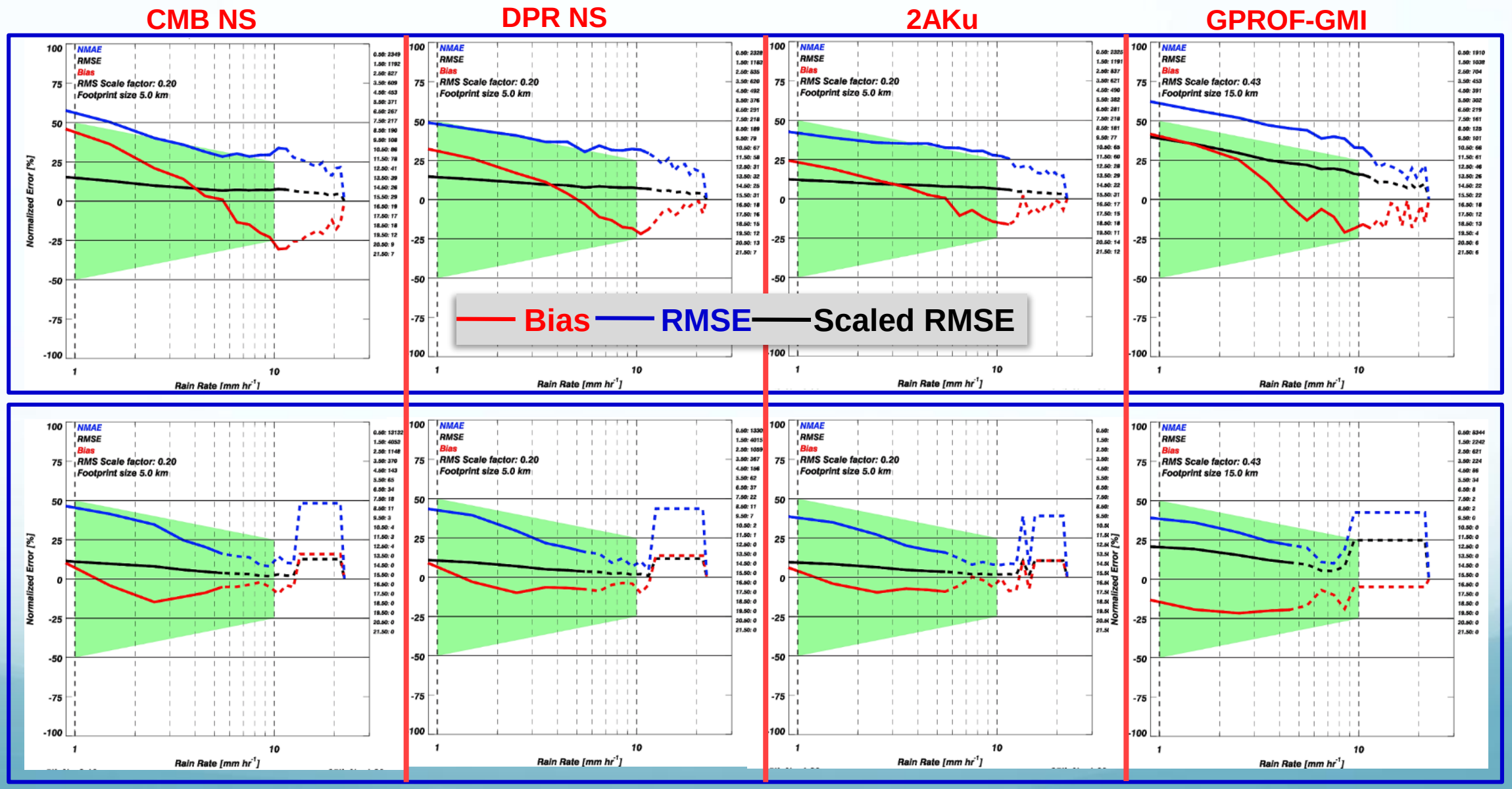
Conditional bias for V5 at footprint scale < 1% for V5

L1
Footprint:
0.2-110 mm/hr

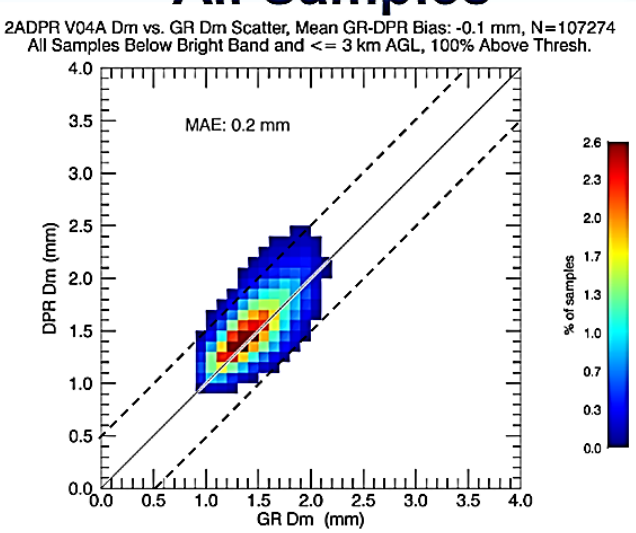
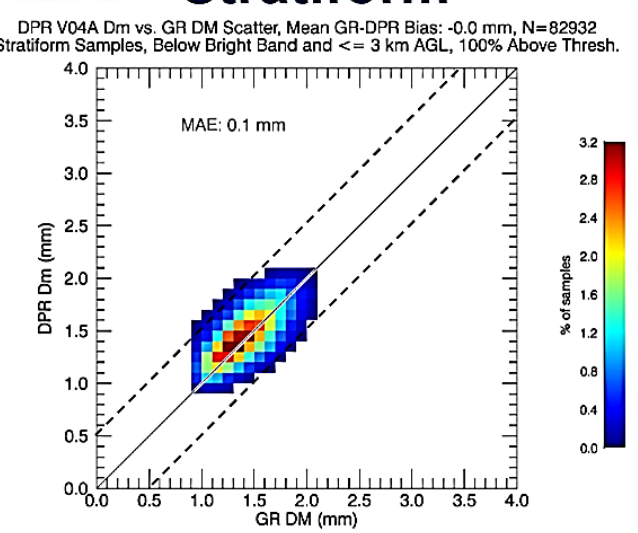
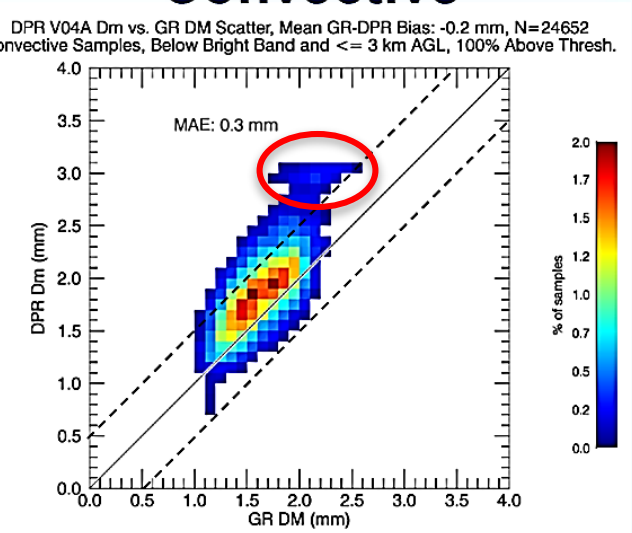
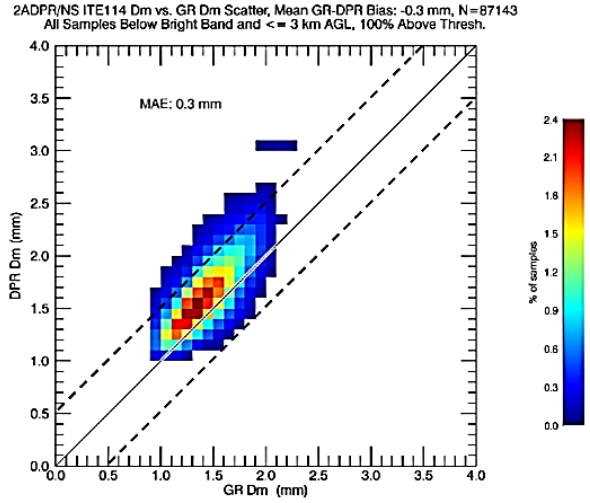
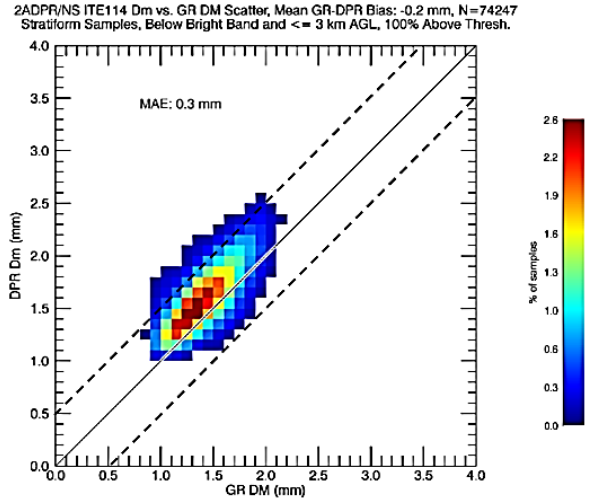
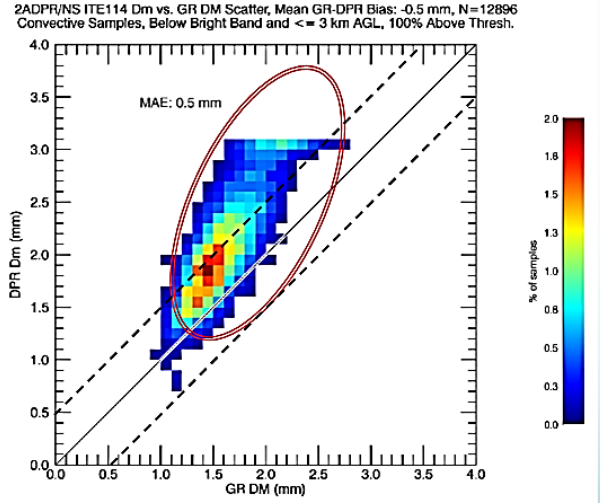
50 x 50 km
Bias
NMAE

Ocean Radar (PAIH and KWAJ) **Footprint (L1 proxy) Rain Rates** V5

L1 requirements met (similar behavior to V4 with sporadic improvement)
Sensitivity to regime, beam filling and footprint size



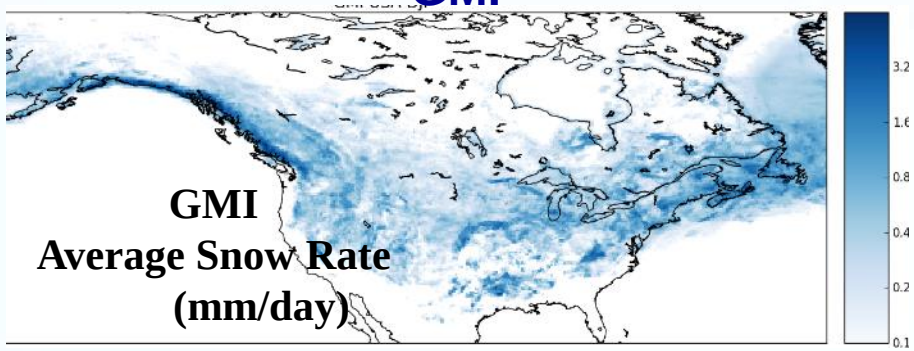
L1 DSD: DPR MS V4, V5 vs. GV Radar D_m

	All Samples	Stratiform	Convective
V4			
V5			

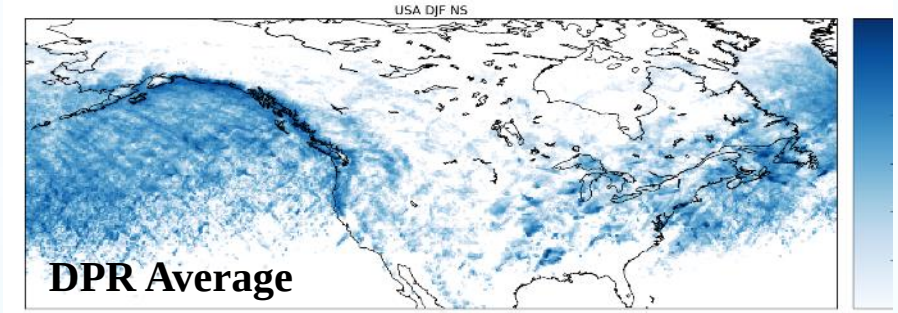
L1: Within limits…But..V5 Positive bias in D_m relative to GV; Convective deviates more from V4 (large Dm mode?)

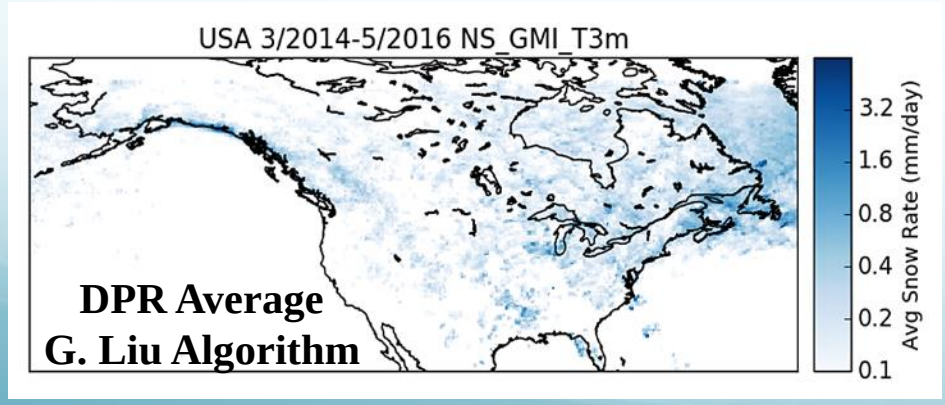
SNOW: "Demonstrate *Detection*" ……

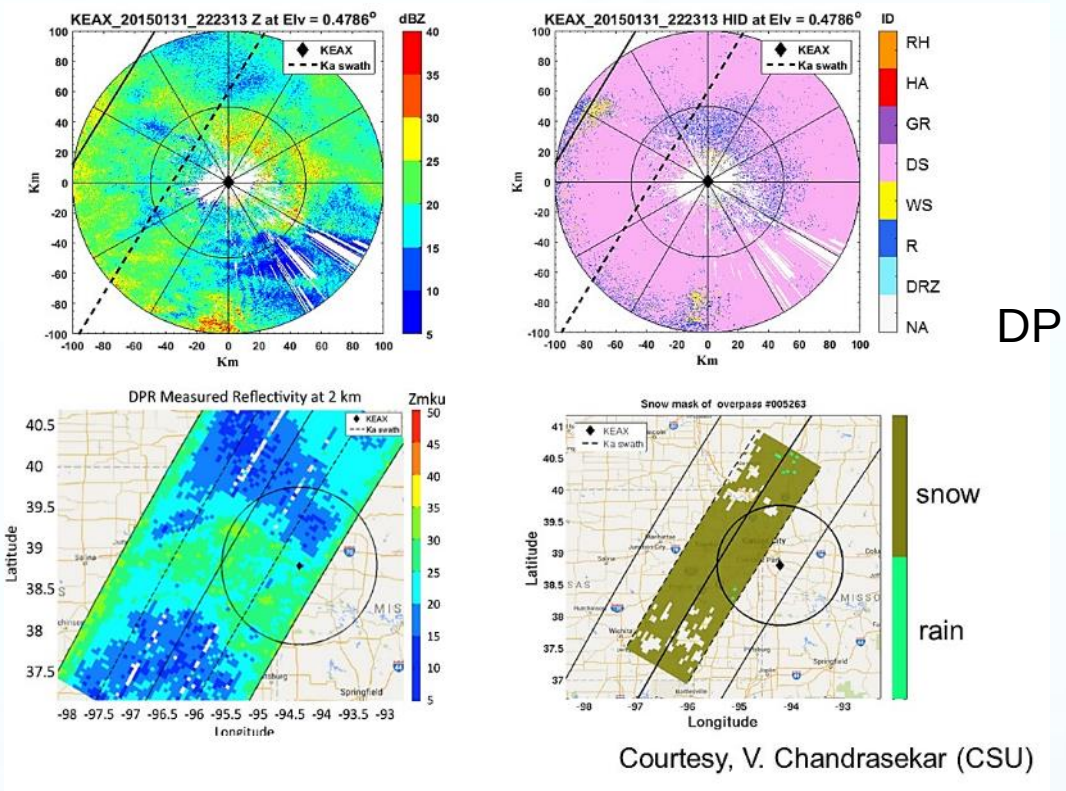
GMI



DPR







DPR MS

Courtesy, V. Chandrasekar (CSU)

Many ways to do this and the instrument and algorithm make a difference! Can use differences as an opportunity!

Quantifying Snow "Detection" and Rain-Snow "Delineation"

MRMS "reference" data. Heidke Skill Score (HSS) used to balance hits, misses, false alarms, correct rejects.

Delineation: Skill at separating rain/snow (MRMS determines "type").

Detection: At what threshold rate do we "see" snow?

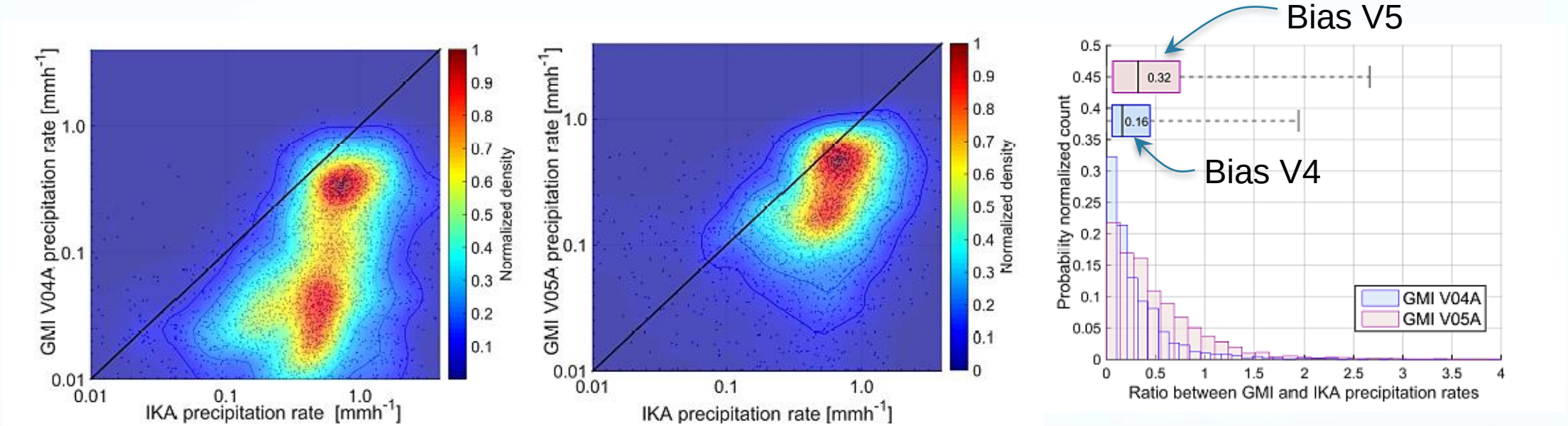
V5

Product	Detection HSS / Threshold	Delineation HSS
GMI GPROF	0.36 / 0.58 mm hr^{-1}	0.85
DPR MS	0.49 / 0.58 mm hr^{-1}	0.66
CMB MS	0.57 / 0.63 mm hr^{-1}	0.67
DPR NS	0.43 / 0.58 mm hr^{-1}	0.65
KuPR	0.44 / 0.58 mm hr^{-1}	0.65

- Detection threshold ~ 0.6 mm/hr for radar and radiometer
- Radar skill delineating rain/snow *at* the surface a bit lower than radiometer- somewhat expected.

Density-Tuned Finland GV Snow estimates vs. GMI-GPROF: Improvements in V5

26 GMI overpasses of the Ikaalinin radar domain in central Finland (2014-2016). Z-S tuned using combination of particle imaging, disdrometers and bulk weighing gauges at Hyytialla, Finland UH/FMI/NASA GV site.



- V5 GPROF snowfall estimation shows a marked improvement in bias relative to V4 over Finland GV site.
- Positive impact(s) of GPROF reduction in light precipitation frequency, and empirically-driven database correction based on MRMS rates detected over snow-covered terrain?

von Lerber, A., D. Moisseev, D. Marks, W. Petersen, A. Harri, V. Chandrasekar, 2017: Validation of satellite-based snowfall products by using a combination of weather radar and surface observations. J. Appl. Meteor. and Clim., in review.

Summary

Radar-based continental-scale GV datasets used to assess GPM Science Requirements: 1) gauge-bias adjusted MRMS rain rates and snow products at 2 minute temporal and 0.01º spatial resolution; 2) Polarimetric radar-based estimates of the DSD (e.g., D_m), volume matched to GPM DPR footprints using VN architecture.

GPM meets "Level 1" science requirements for GPM Core Satellite products: footprint to 50 km scales, rain rate, DSD (hard requirement on D_m), and “demonstrating” detection of snow.

- ✓ L1 rain requirements demonstrated over continental U.S. and two different GV ocean sites (tropical and high latitude) for GPM Core V4 and V5 products [exception GMI GPROF random error over continental U.S.].
- ✓ DSD requirement is met. Noted shift in DSD behavior in V5 to high bias (relative to GV) due to a change in radar calibration. Specific departures/differences from GV in convective precipitation require more examination, but partially due to algorithm artifact related to original limit put on D_m.
- ✓ L1 snow detection demonstrated; move to test and further develop estimation of snow water equivalent rates for V6.