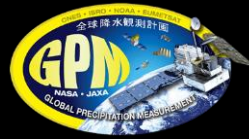# Ground Validation Assessments of GPM Core Observatory Science Requirements

Walt Petersen, NASA-MSFC

George Huffman, NASA-GSFC, Chris Kidd, U. Maryland; Gail Skofronick-Jackson, NASA-GSFC
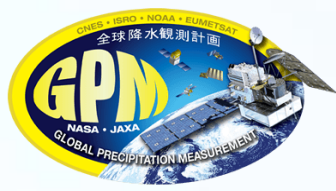
Outline

- **"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.

- At 50 km resolution, space-based *instantaneous* rain rate estimate with *bias and random error < 50% at 1 mm hr^{-1} and < 25% at 10 mm hr^{-1}, relative to calibrated GV*

Data

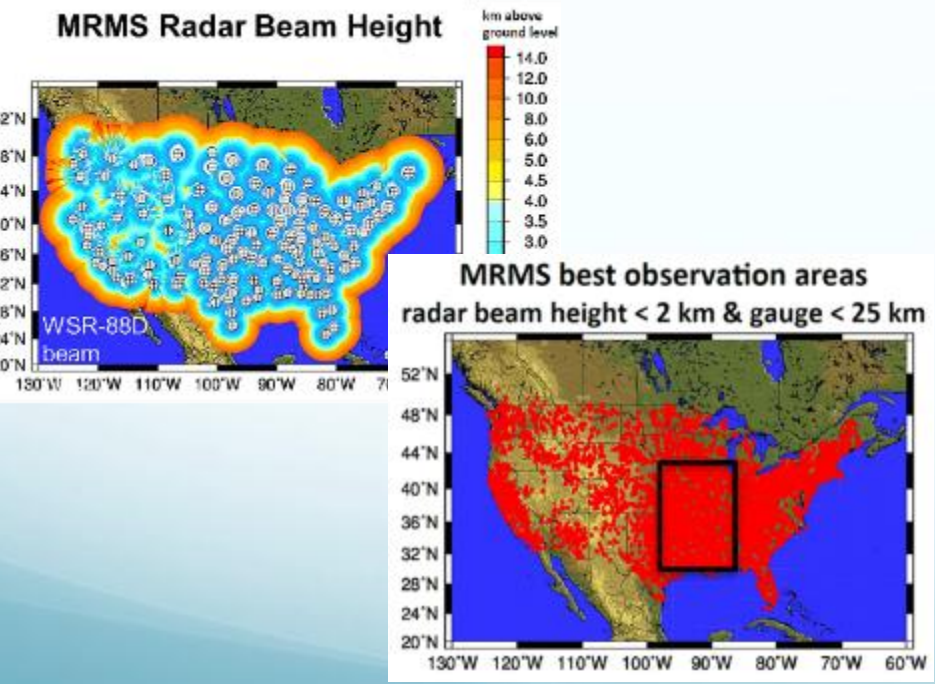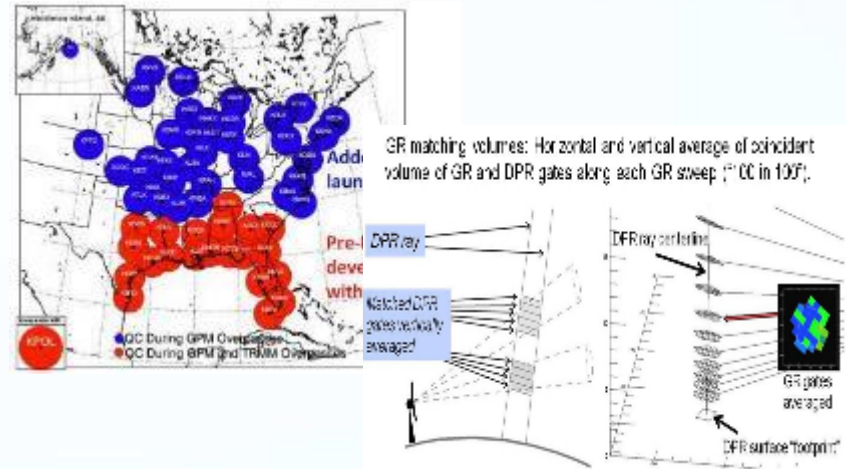## 1) NOAA Multi-Radar Multi-Sensor (MRMS) Precipitation Rates

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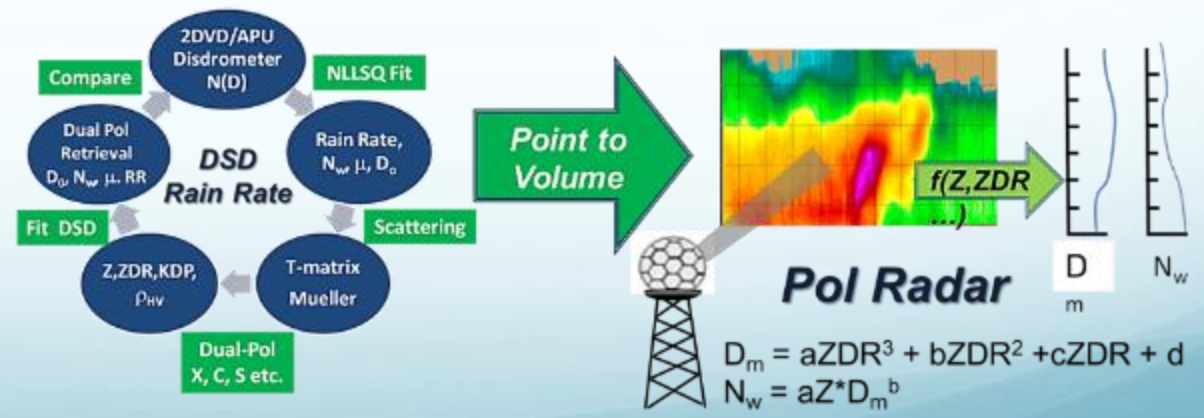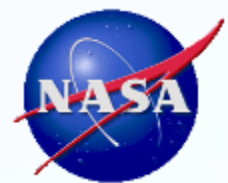- Quality-constrained "reference" subsets created

MRMS Radar Beam Height

MRMS best observation areas
radar beam height < 2 km & gauge < 25 km

2) Validation Network

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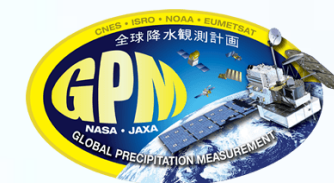- 65 US + numerous research and international radars

GR matching volumes: Horizontal and vertical average of coincident volume of GR and DPR gates along each GR sweep (0°C in 100°).

3) Field site observations

- Disdrometer, Radar, Dense Gauge network

DSD Rain Rate

Point to Volume

Pol Radar

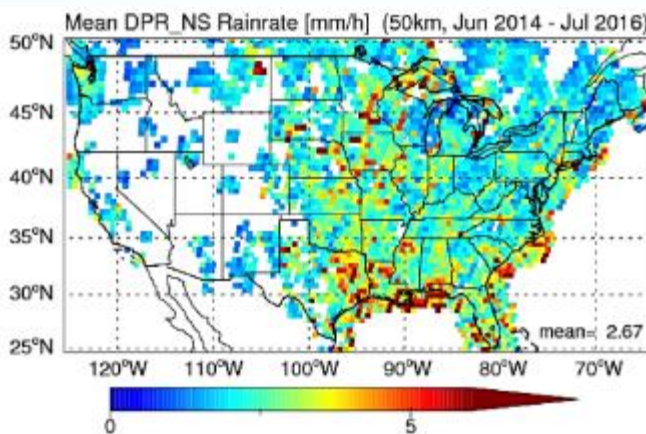$D_m = aZDR^3 + bZDR^2 + cZDR + d$

$N_w = aZ*D_m^b$

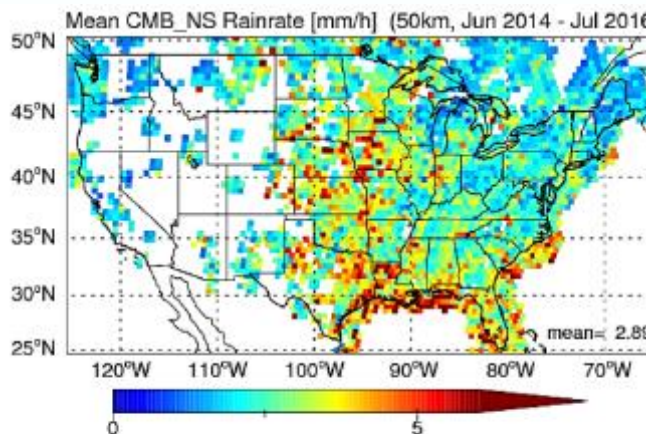# Rain: General Continental Context (50 x 50 km)

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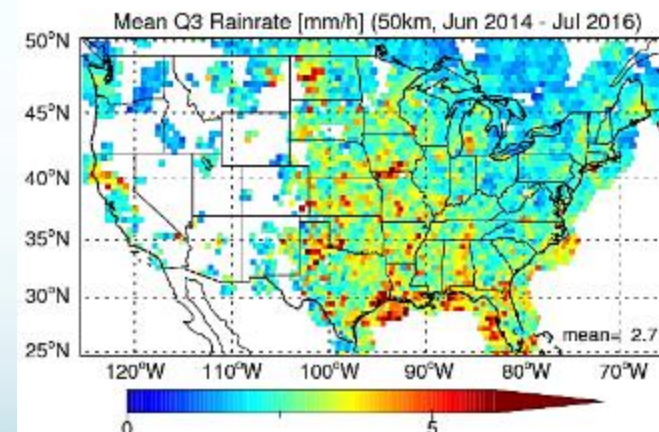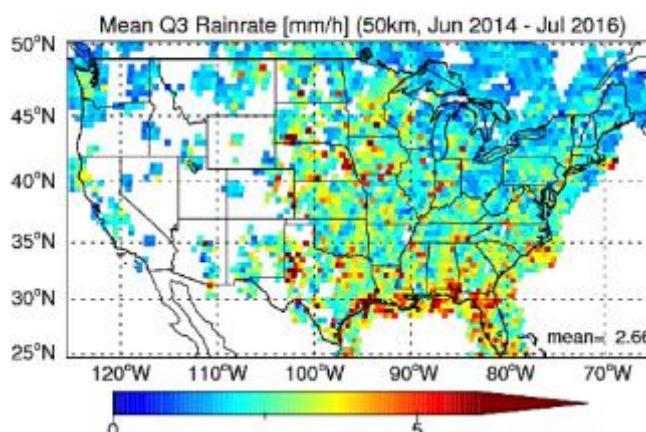Conditioned on 0.2 mm/hr threshold at FOV
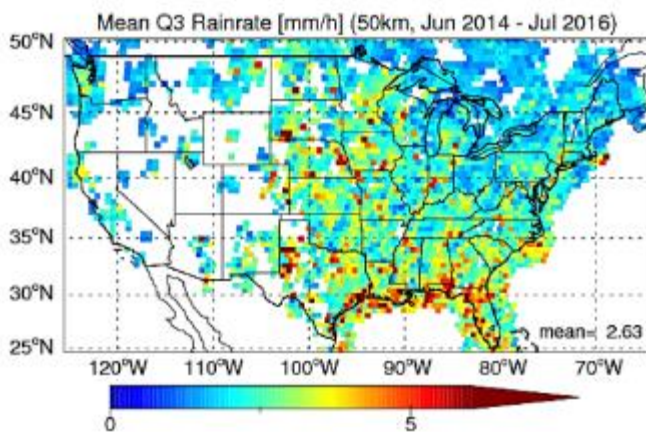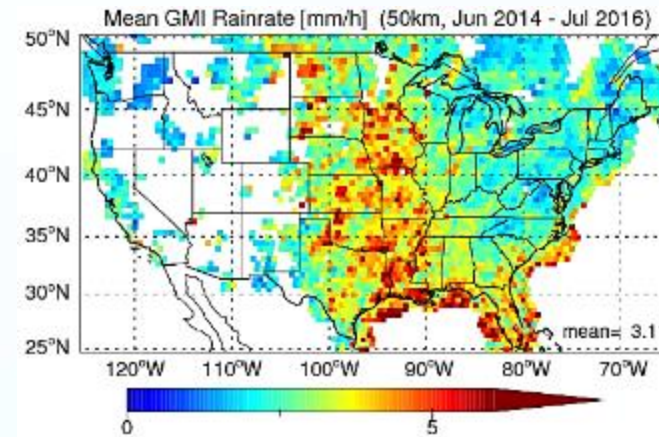

- Check to product to product variability- e.g., V5 DPR products all in good agreement with GV (similar to V4)
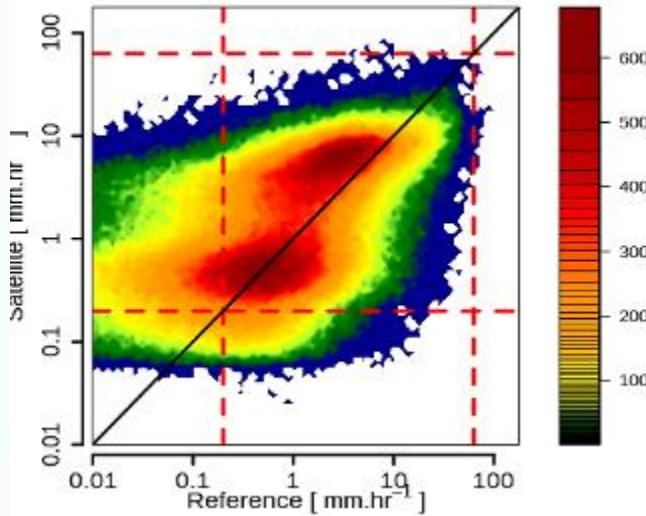- Radar products in better agreement with MRMS; GPROF estimate in "MCS alley" still a little high.

V4 and V5 GPROF GMI, and L1 **Rain Rate** vs. GV MRMS
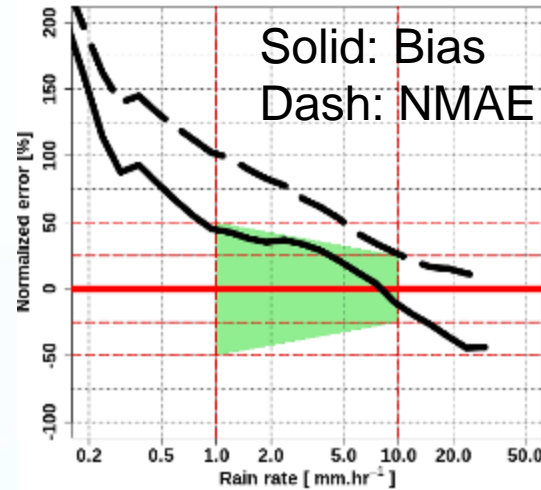
Footprint (15 km)

Level 1 (50 km)

V4

Footprint:
Correlation 0.47, bias 24.6%- non-uniform and with modes;
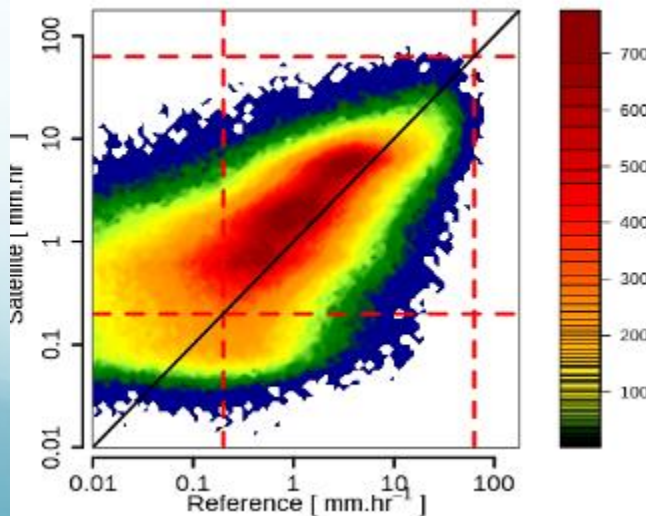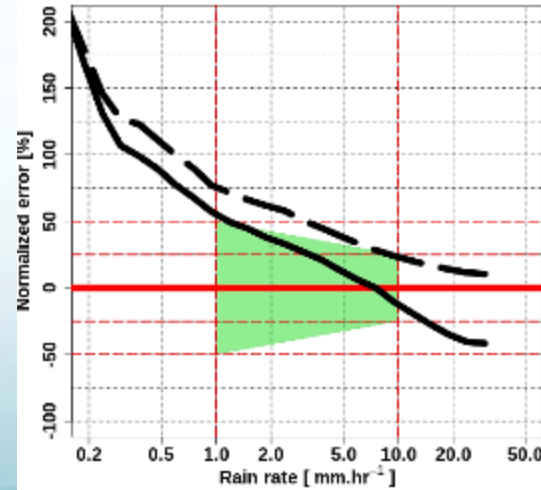
L1:
Footprint:
　　Range of 0.2 - 60 mm/hr
50 x 50 km
　　Bias
　　Random error (NMAE)

V5

Footprint:
Correlation 0.57, bias 20 %;
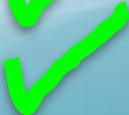Smoother bias, reduced NMAE; greater extension to light rain;
L1:
Footprint:
50x50km
　　Bias: (better)
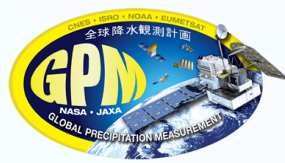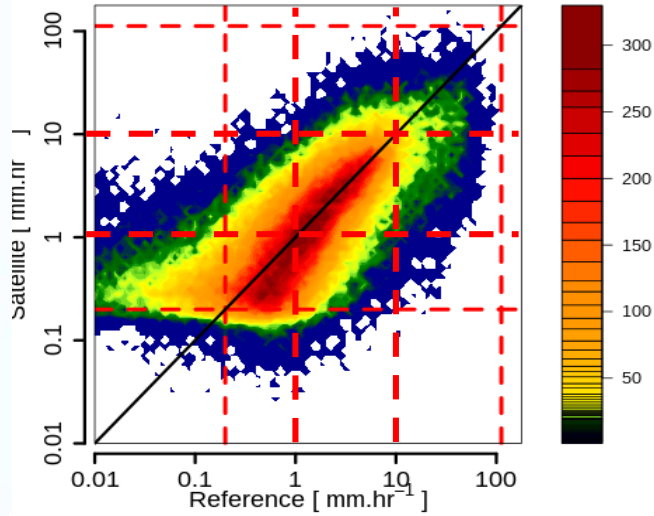　　NMAE: (still a bit high)

Solid: Bias
Dash: NMAE

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

Footprint (~ 5 km)

Level 1 (50 km)

Solid: Bias
Dash: NMAE

V4
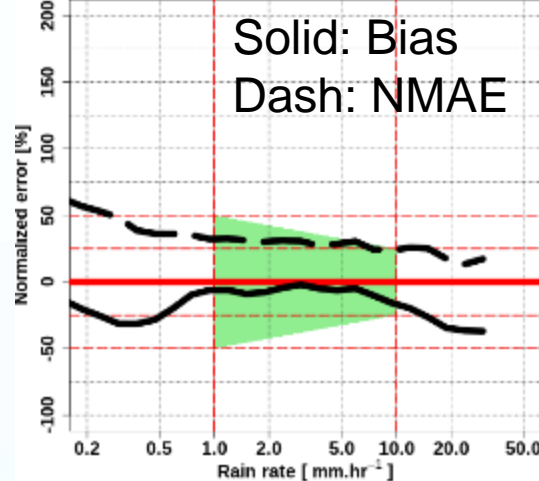
V5
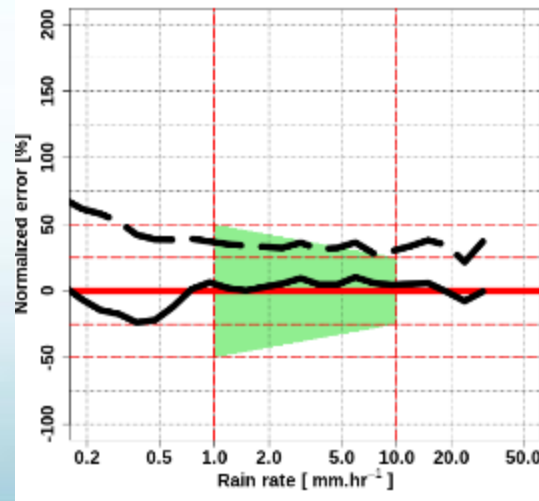
V4 ok, V5 better!
- V5 Conditional bias < 12%

<u>L1:</u>
Footprint:
    0.2-110* mm/hr
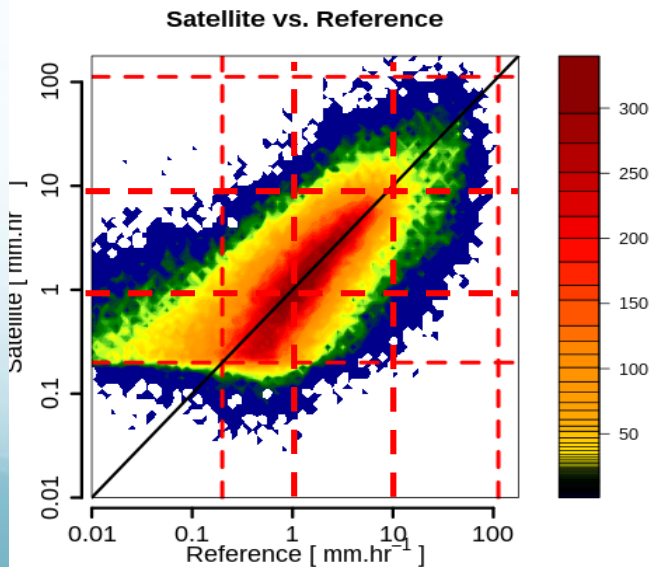   (*sample numbers at >100
    mm/hr; < 0.01%)

50 x 50 km
    Bias
    NMAE (improved V5)

V4 and V5 **Combined Alg. MS**: **Rain Rate** vs. GV MRMS
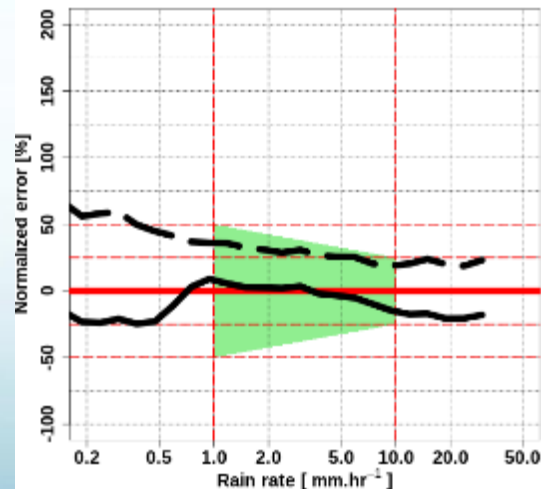
Footprint (~ 5 km)

Level 1 (50 km)

Solid: Bias
Dash; NMAE
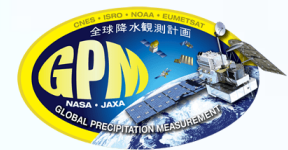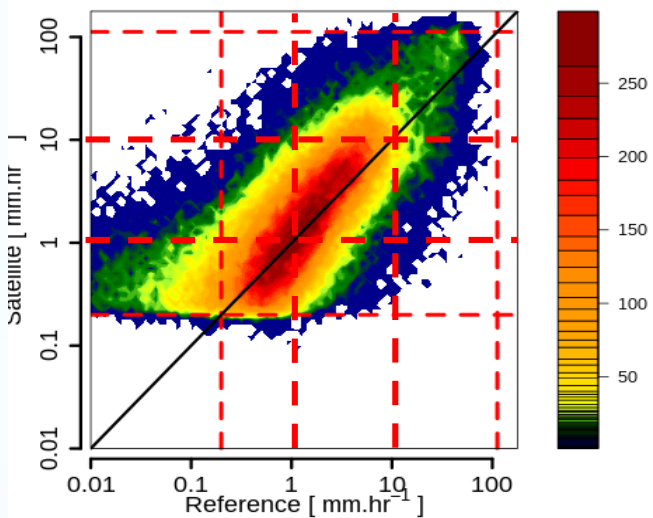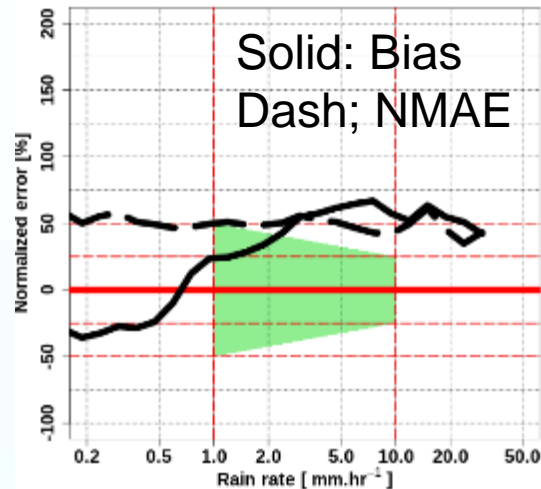
Relative to V4 (top; had known issues), V5 (bottom) is **MUCH** improved!
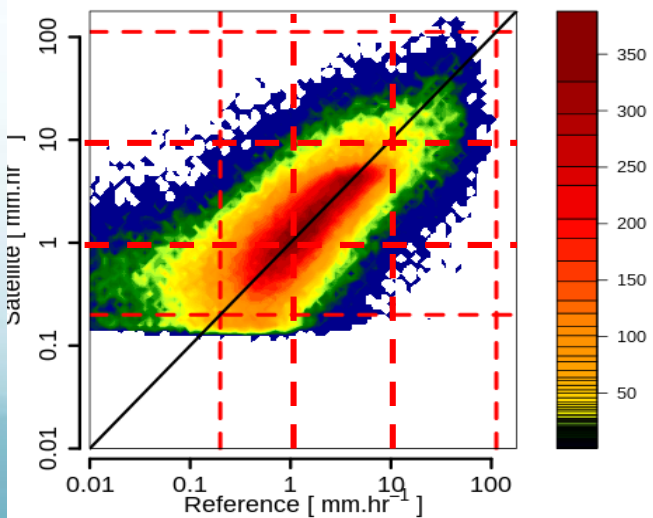
Conditional bias for V5 at footprint scale < 1% for V5

L1
Footprint:
  0.2-110 mm/hr

50 x 50 km
  Bias
  NMAE

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

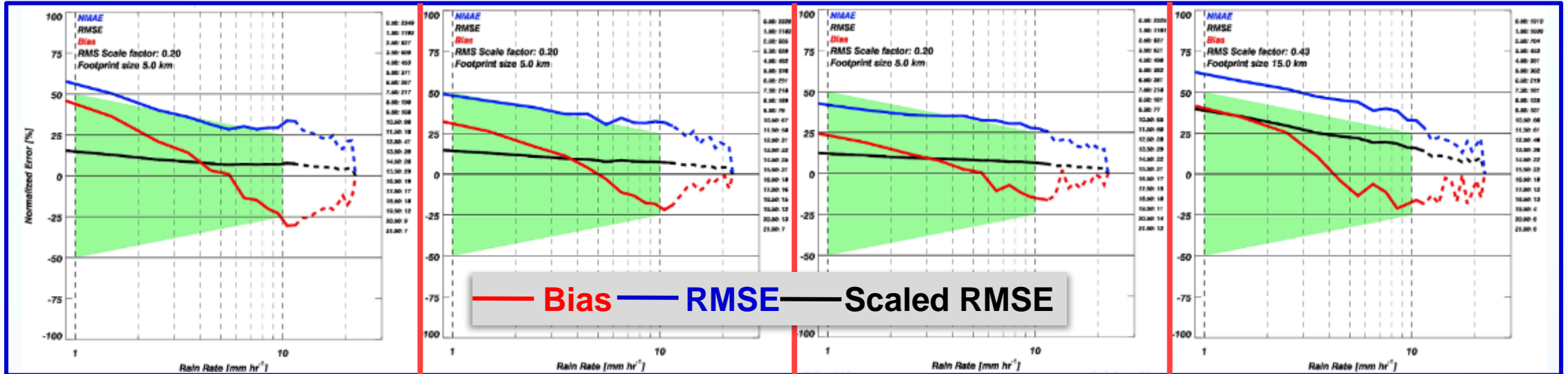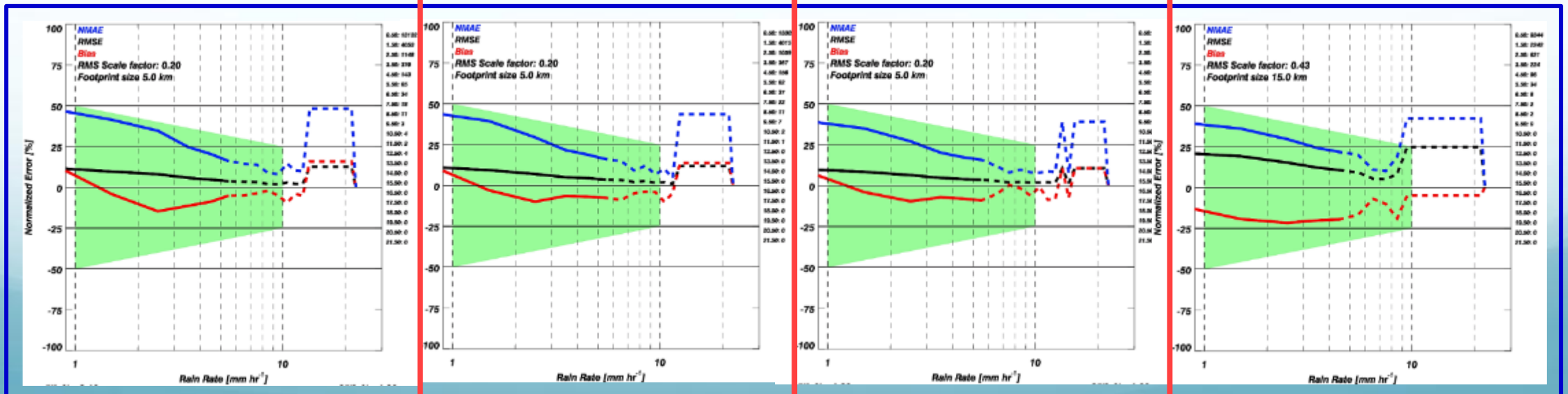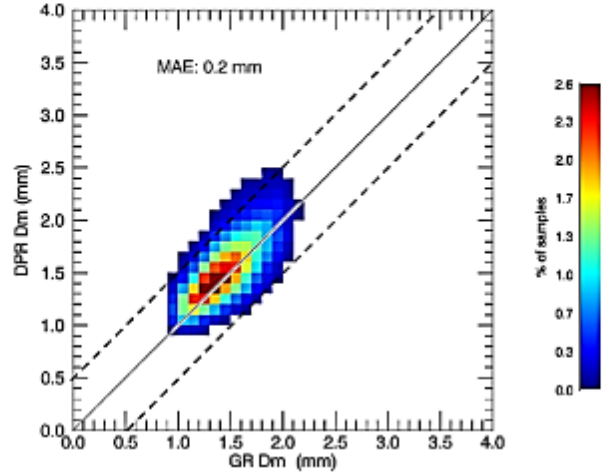**CMB NS**   **DPR NS**   **2AKu**   **GPROF-GMI**

KWAJ (8°N)

PAIH (60° N)

Legend: Bias   RMSE   Scaled RMSE

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

GMI

GMI Average Snow Rate (mm/day)

DPR

DPR Average

USA 3/2014-5/2016 NS_GMI_T3m

DPR Average G. Liu Algorithm
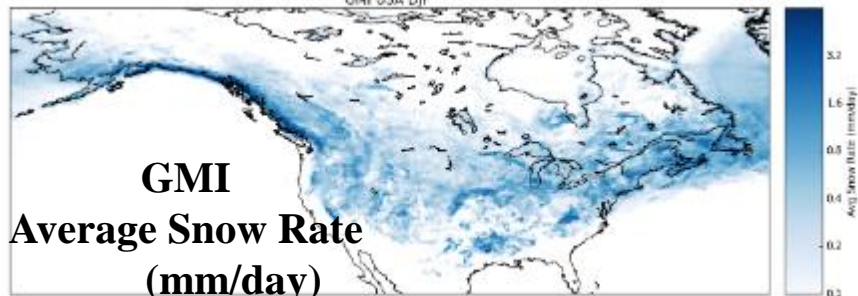
Version 5: New DFRm snow-Index (Le and Chandra): Validation using 88D HID algorithms against DPR MS
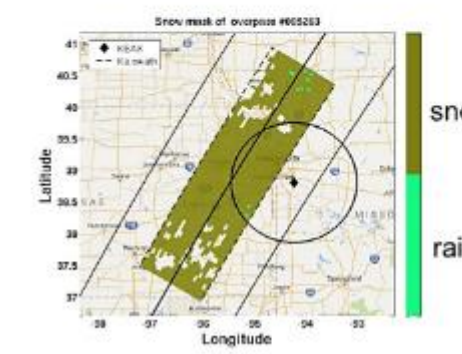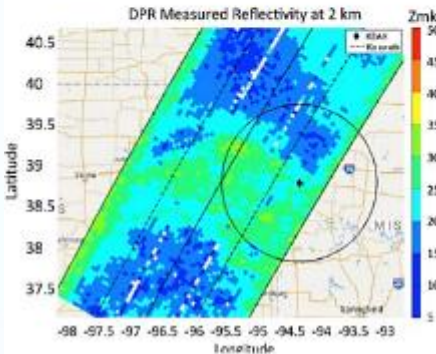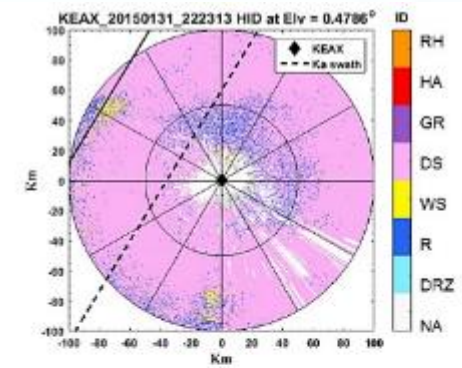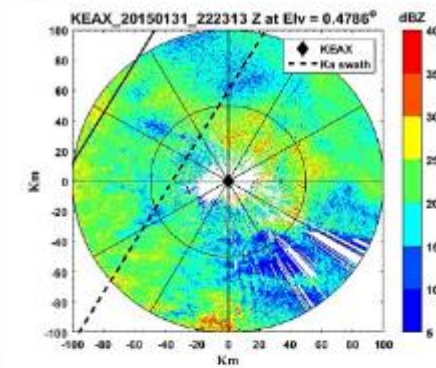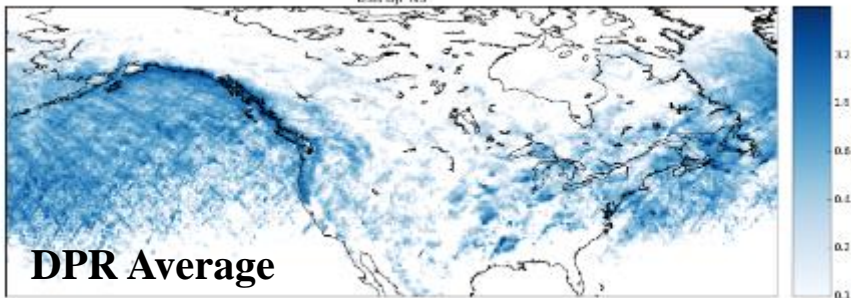
Courtesy, V. Chandrasekar (CSU)
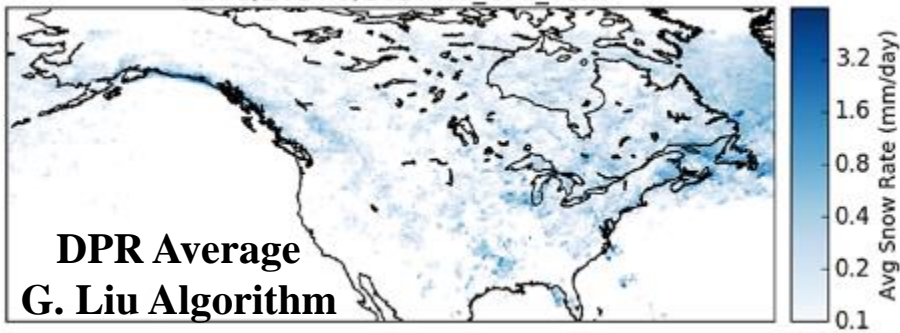
This essentially demonstrates detection and satisfies requirements but……difference in algorithms related to assignment of snow at/near the surface.

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

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

Delineation: MRMS determines "type" (rain or snow). HSS maximized against the reference type.

Detection: HSS maximized for the satellite as a function of MRMS snow water equivalent rate (SWER); the "detection" threshold then corresponds to the SWER at the inflection point of the HSS curve.

Product	Detection HSS / Threshold	Delineation HSS
GMI GPROF*	0.43 / 0.63 mm hr^{-1}	0.77
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

* Need to include snow/ice-covered surfaces when doing the statistics

- Detection threshold ~ 0.5-0.7 mm/hr for radar and radiometer consistent with theory and previous observational comparisons to gauges in U.S. (at least for radar)
- Radar product HSS for delineating rain/snow *at* the surface a bit lower than radiometer

Summary

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

- U.S. national network and research radar, disdrometer and gauge assets bridge point to satellite footprint scales, thus creating statistical validation datasets. Supplemental datasets (gauges, radars etc.) from other regions and international partners also used to help evaluate basic trends between products.

✓ L1 rain requirements demonstrated over the continental U.S. and two different ocean sites (tropical and high latitude) for GPM Version 4 and Version 5 products [exception GMI GPROF random error over continental U.S.].

✓ L1 DSD requirements satisfied for V4 and V5 algorithms. Shift in DSD behavior in V5 needs to be examined.

✓ L1 snow detection demonstrated and now expect stronger emphasis to be put on more robust estimation of SWER- possibly V6.

- GPM Version 5 products will be available by early May 2017 (see Erich Stocker, PPS, for details)
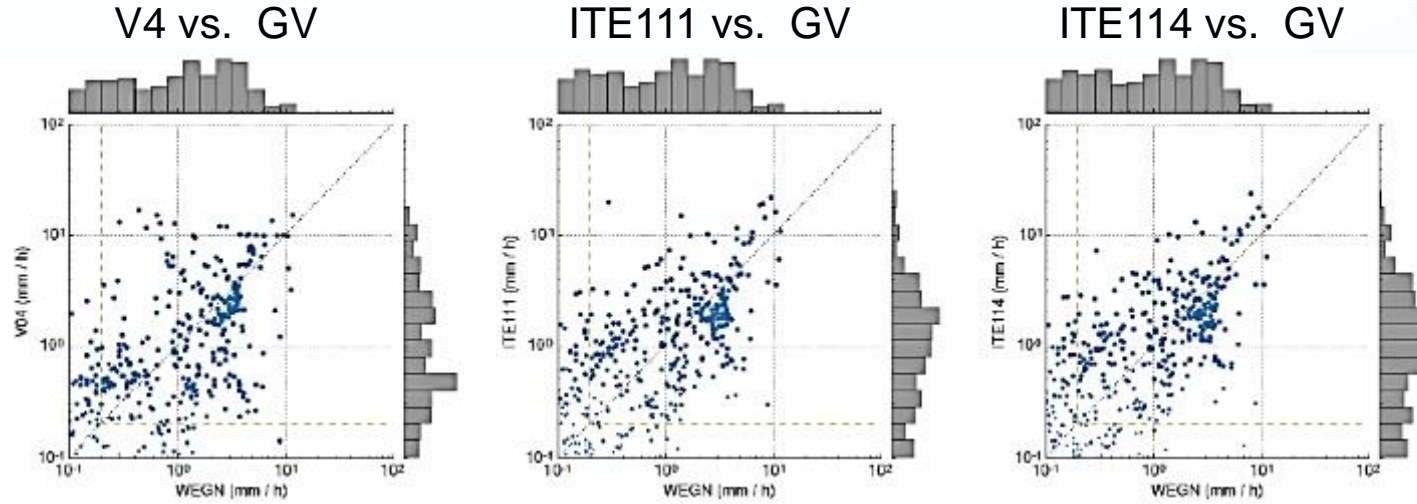
EXTRA

Rain Rate Footprints and Gauges: GPROF GMI V4 to ITE 114
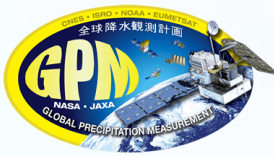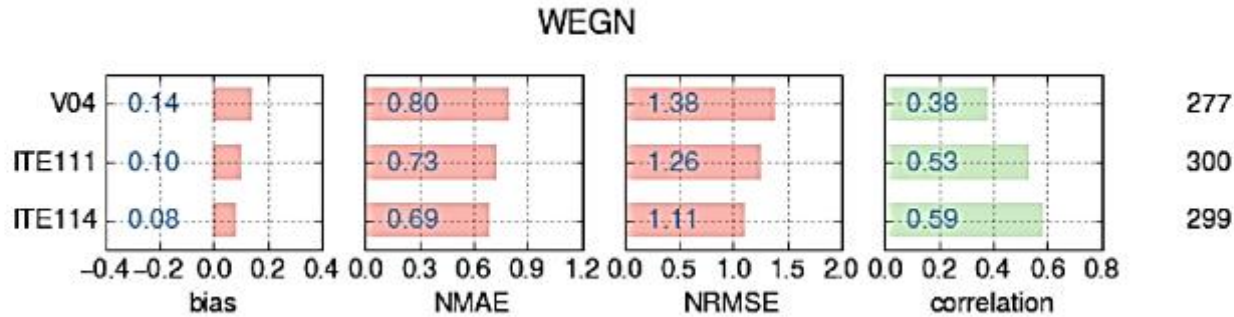
1 Gauge every ~ 1 km²
Require: Minimum 12-gauges/15 km footprint, 15 minute accumulation
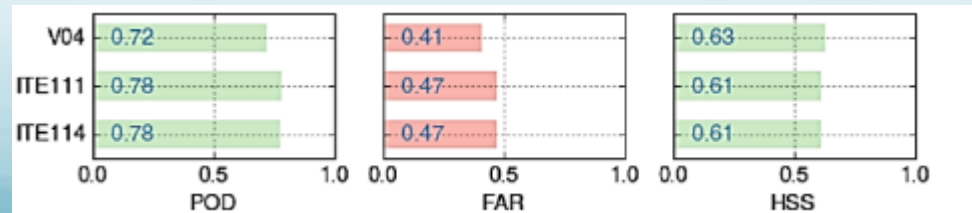
Example:
WegenerNet, Austria

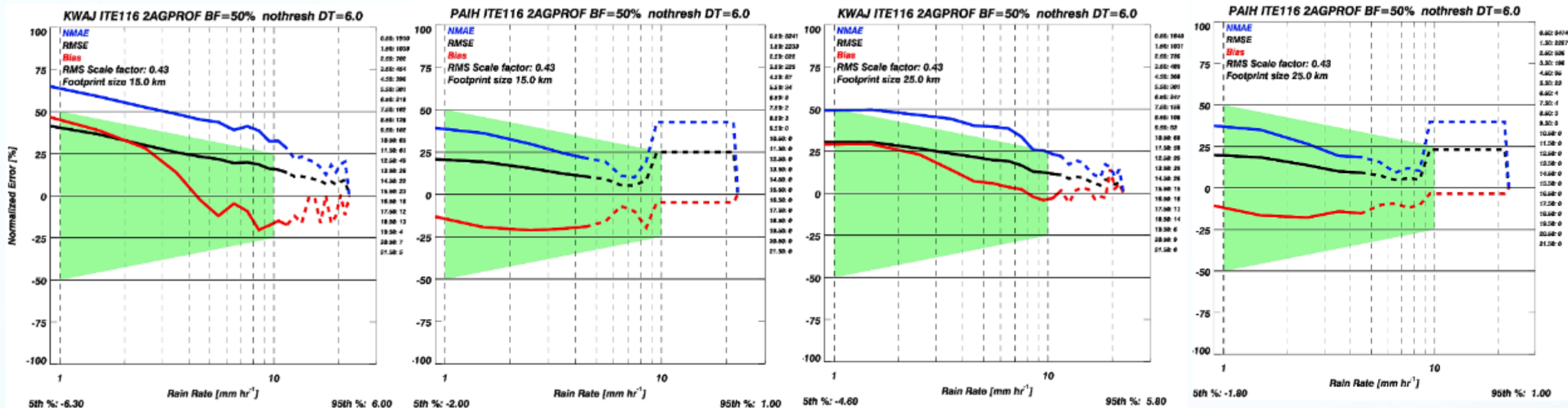Good for tracking steady improvements in product.

Intensity

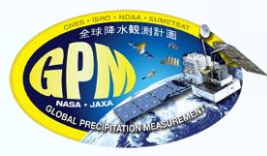….but low sample numbers at this stage of the mission impact scores……
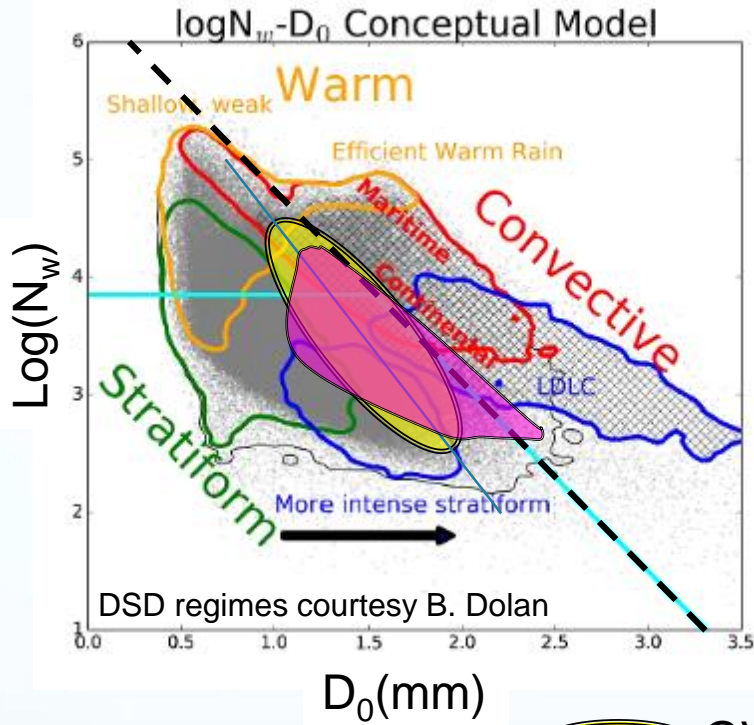
Detection

Bias and Random error at 15 km footprint scale are within L1 over Ocean sites and generally improve by going to a 25 km footprint- more consistent with true "effective" footprint of algorithm over ocean.
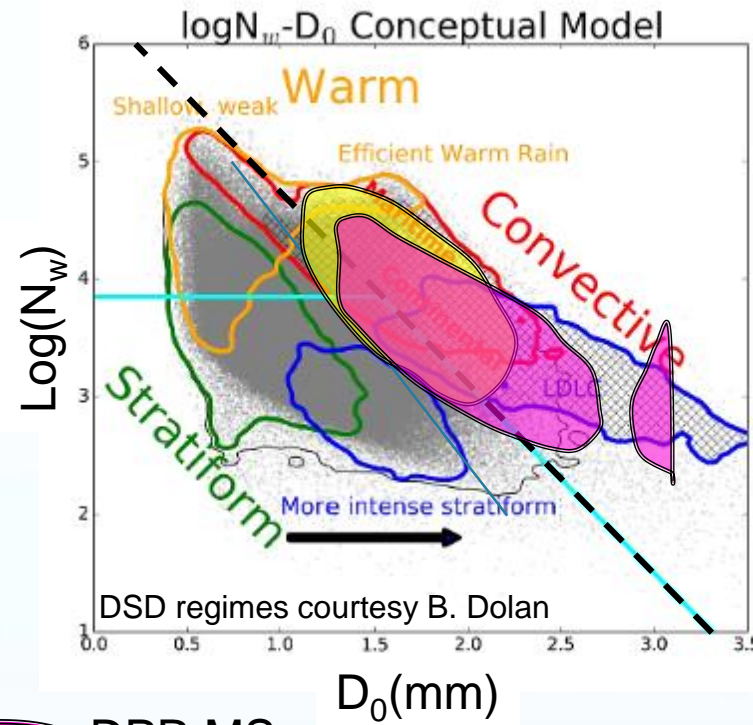
DSD: V5 DPR MS Convective D_m and N_w

GV 2DVD D_o vs N_w

GV 2DVD D_o vs N_w

GV   DPR MS

- DPR MS V5 fits GV sample space (Assuming $D_m \approx D_0$); behavior is somewhat similar to GPM GV Radar

- Shift to larger D_m and smaller N_w relative to GV; secondary mode at large D_m

- Combined algorithm (not shown) also generally "fits" GV - but with different N_w-D_m slope behavior in stratiform