Ground Validation Assessments of GPM Core Observatory Science Requirements


Acknowledged Contributions:
P. Kirstetter, D. Wolff, D. Marks, K. Morris, T. Berendes, V. Chandrasekar, M. Schwaller, J. Tan

- "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.
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

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

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

- 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)**

- V4: Footprint: Correlation 0.47, bias 24.6% - non-uniform and with modes;
- L1: Footprint: Range of 0.2 - 60 mm/hr,
- Bias: Random error (NMAE)

**Level 1 (50 km)**

- V4: Footprint: Correlation 0.57, bias 20% - Smoother bias, reduced NMAE; greater extension to light rain;
- L1: Footprint: 50x50 km
  - Bias: (better)
  - NMAE: (still a bit high)
- V5: Smoother bias, reduced NMAE; greater extension to light rain; 50x50 km
  - Bias: (better)
  - NMAE: (still a bit high)
V4 and V5 DPR MS, and L1 Rain Rate vs. GV MRMS

Footprint (~ 5 km)
Satellite vs. Reference
V4
V5

Level 1 (50 km)
Solid: Bias
Dash: NMAE

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

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

50 x 50 km
Bias
NMAE (improved V5)
Relative to V4, V5 is **MUCH** improved!

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

---

**Footprint (~ 5 km)**

**Level 1 (50 km)**

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
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 $D_m$

L1: Within limits...But..V5 Positive bias in $D_m$ relative to GV; Convective deviates more from V4 (large $D_m$ mode?)
SNOW: “Demonstrate Detection” …..

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?

<table>
<thead>
<tr>
<th>Product</th>
<th>Detection HSS / Threshold</th>
<th>Delineation HSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMI GPROF</td>
<td>0.36 / 0.58 mm hr⁻¹</td>
<td>0.85</td>
</tr>
<tr>
<td>DPR MS</td>
<td>0.49 / 0.58 mm hr⁻¹</td>
<td>0.66</td>
</tr>
<tr>
<td>CMB MS</td>
<td>0.57 / 0.63 mm hr⁻¹</td>
<td>0.67</td>
</tr>
<tr>
<td>DPR NS</td>
<td>0.43 / 0.58 mm hr⁻¹</td>
<td>0.65</td>
</tr>
<tr>
<td>KuPR</td>
<td>0.44 / 0.58 mm hr⁻¹</td>
<td>0.65</td>
</tr>
</tbody>
</table>

- 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


- 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?

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 0.01° 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.