GPM Product Evaluations, Algorithms, and Processes: GV in the Post-Launch and Extended Mission

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- **Requirements and reference comparisons**
- **DSD consistency**
- **Snow water equivalent**
- **Orographic Precipitation**
- **IMERG**

Leaving off from 2016/17…..

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*.

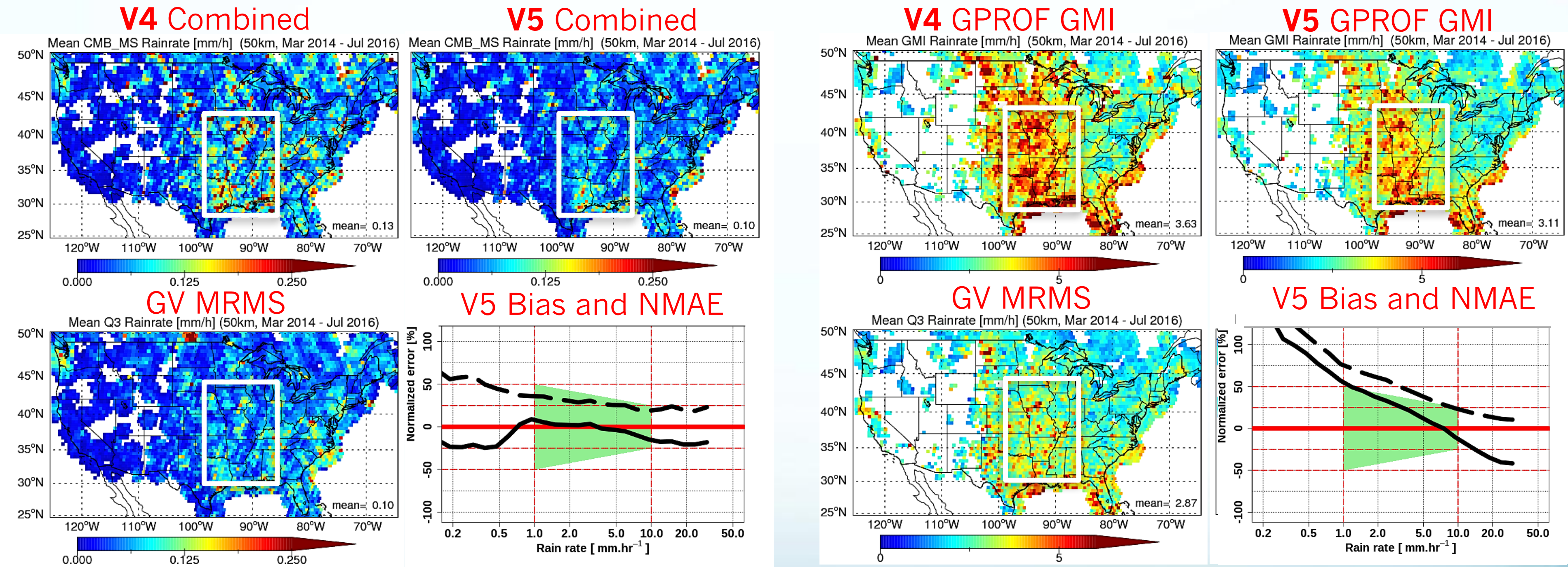
- GMI: *quantify rain rates* between 0.22 and 60 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 15 km*.

- Core observatory radar estimation of the Drop Size Distribution (DSD)- specifically, D_m *to within +/- 0.5 mm*. [note- no N_w requirement]

- Core observatory *instantaneou*s 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*

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

CONUS Mar 14 – July 16: GV MRMS vs. Combined MS, and GMI GPROF **V4 and V5**
(Liquid only, RQI > 0.9; GMI-GPROF- Conditioned on 0.2 mm/hr threshold at FOV)



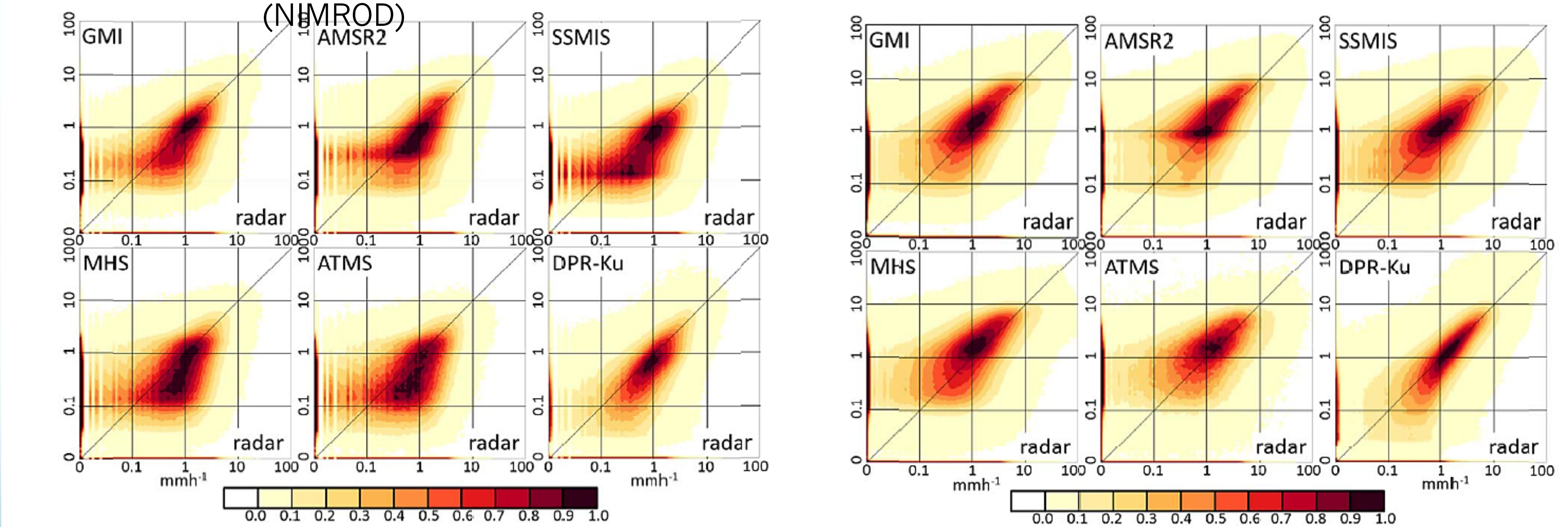
- Marked improvement in Combined Algorithm from V4 to V5; L1 Requirement is met!
- V5 Radar-based products (both DPR and CMB) in good agreement with MRMS; GPROF V5 in "MCS alley" still a little high, but *bias and RE not necessarily uniform by region or rain rate*.

What about differing regimes? E. U.S. to W. Europe

Carefully-selected gauge-corrected radar (NIMROD, MRMS) estimates at 15 km scale

W. Europe (NIMROD)

E. U.S. (MRMS)

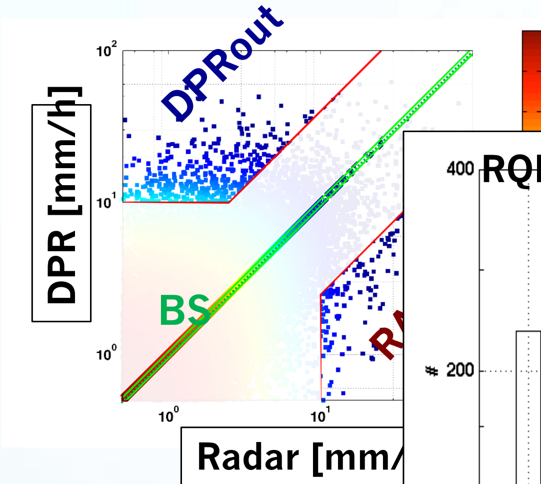


Need to continue to expand larger scale "*reference*" comparisons in other regions of the globe

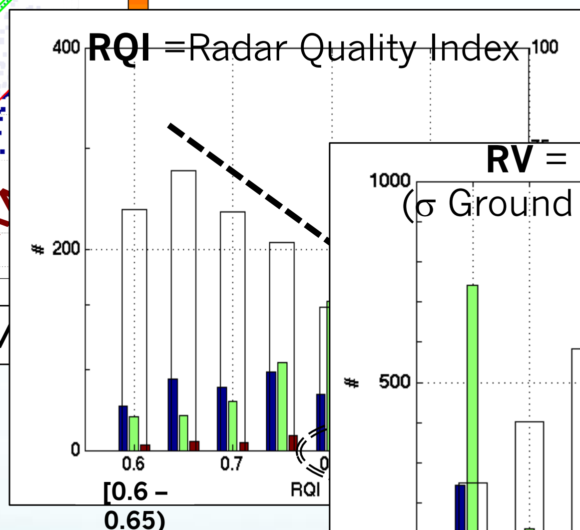
Kidd et al., 2017, QJRMS

HSAF/Italy: DPR NS Comparisons and Sensitivity to GV data Conditioning

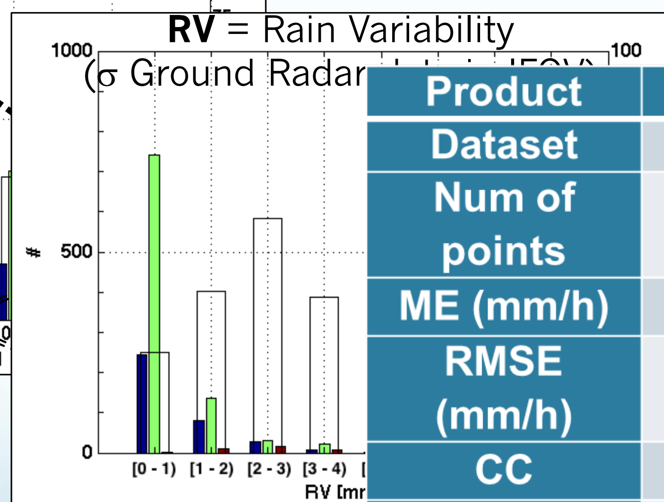
Quality-controlled Italy Radar-Gauge Network Data (HSAF 1x1 km grid every 10 minutes)



"Whole" dataset



How do outliers/error change with RQI?



How do outliers/error change with σ?

We need more diverse regional/global GV-satellite data comparisons- but the comparisons *must* consider quality metric(s) of GV data..........

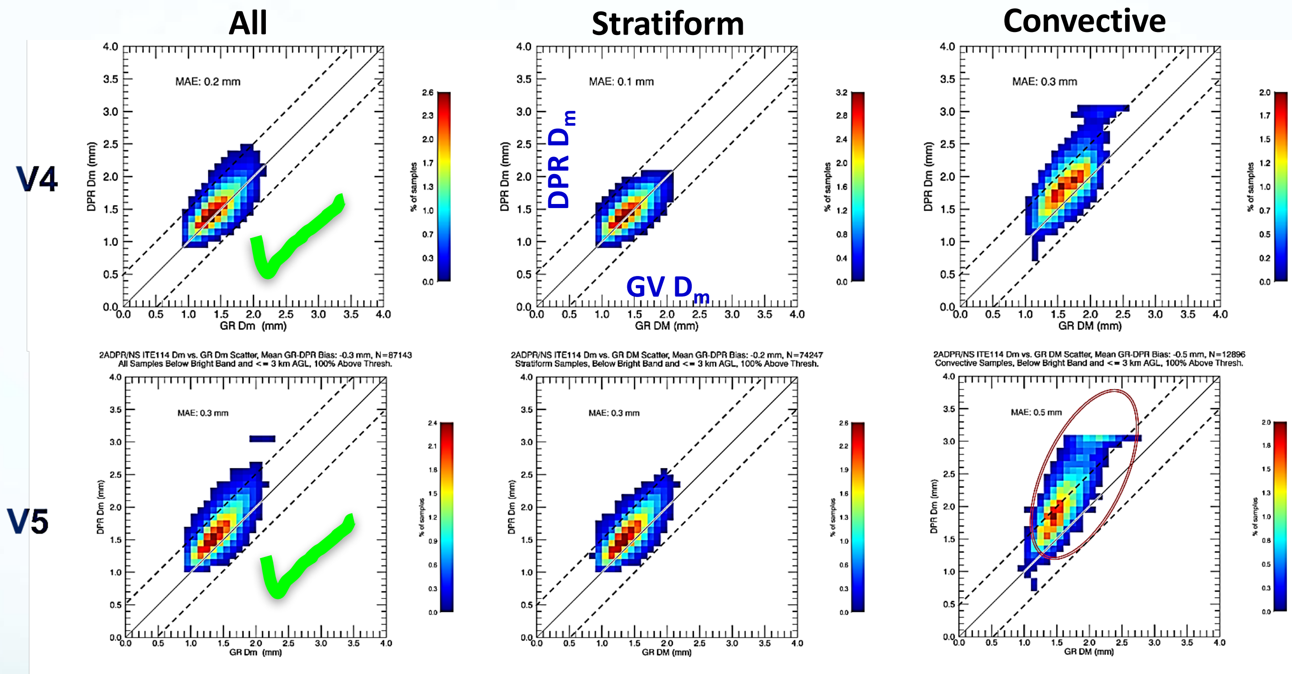
Filter on RQI >0.8, RV < 5 (mm/hR)

Product	DPR NS		
Dataset	Whole	Filtered	Δ%
Num of points	19,597	13,468	-31%
ME (mm/h)	0.32	0.16	-50%
RMSE (mm/h)	4.50	2.89	-36%
CC	0.41	0.52	+27%
FSE (%)	159	111	-30%
POD (%)	93	93	0%
FAR (%)	6	1	-83%

Petracca et al., 2017, 38th AMS Radar Conference

L1 Requirement DSD: Continental Scale VN-GPM Comparisons

DPR MS **V4, V5 D_m** vs. **GV Radar D_m**

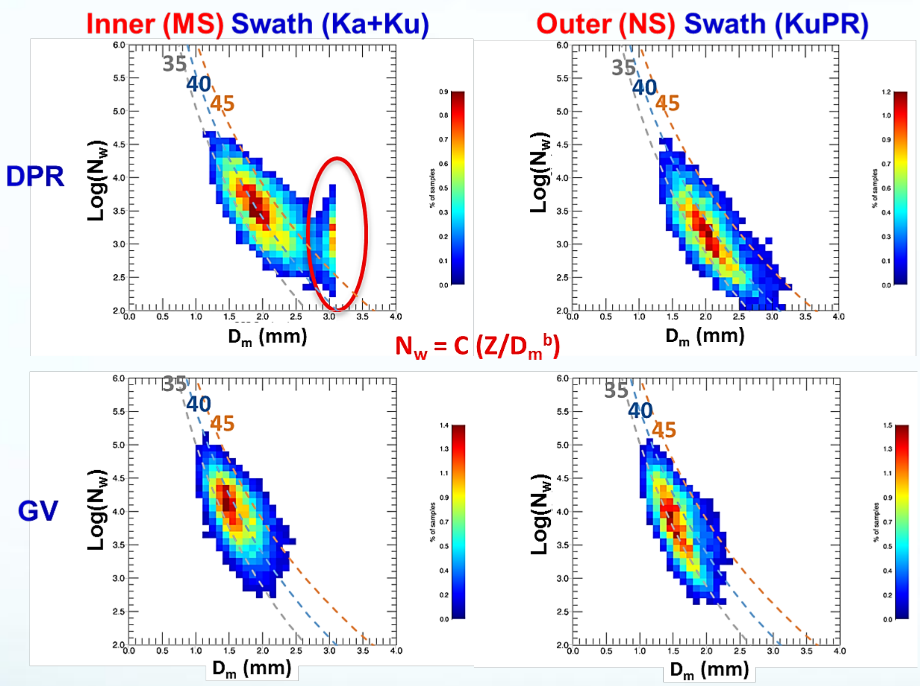


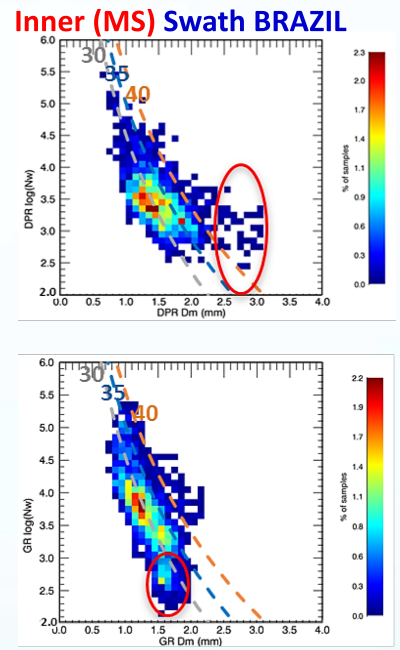
Science requirement: V4 and V5 meet requirement (but more positive bias in V5)

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

- In stratiform precipitation, V5 DPR is about ~0.2 mm higher than GV (= ~0.2 dB cold bias in ZDR), but………….
- 2ADPR Convective D_m bias in V5 increases non-uniformly, secondary mode in convective D_m at 3 mm**(?)**

Closer look at V5 DPR MS: Convective N_w vs. D_m against GV



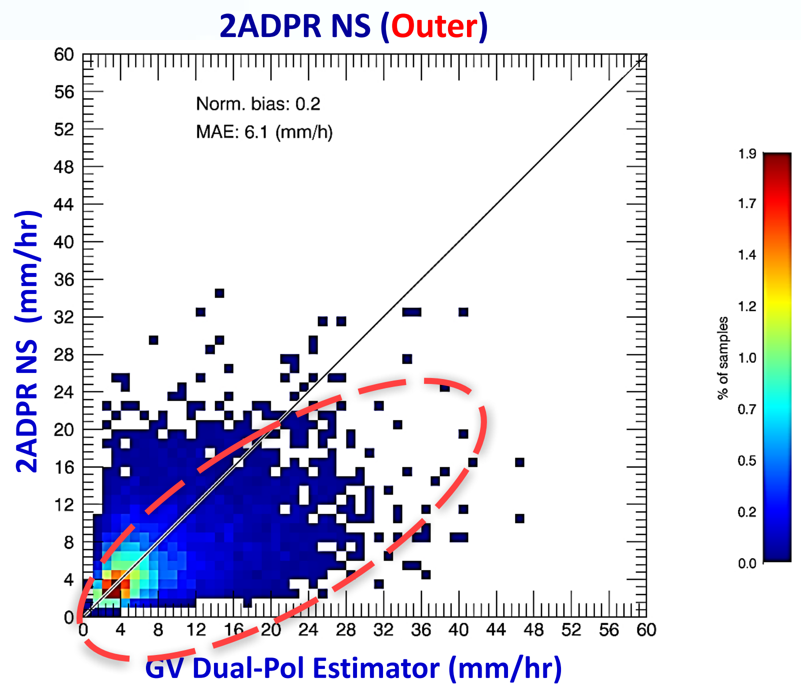


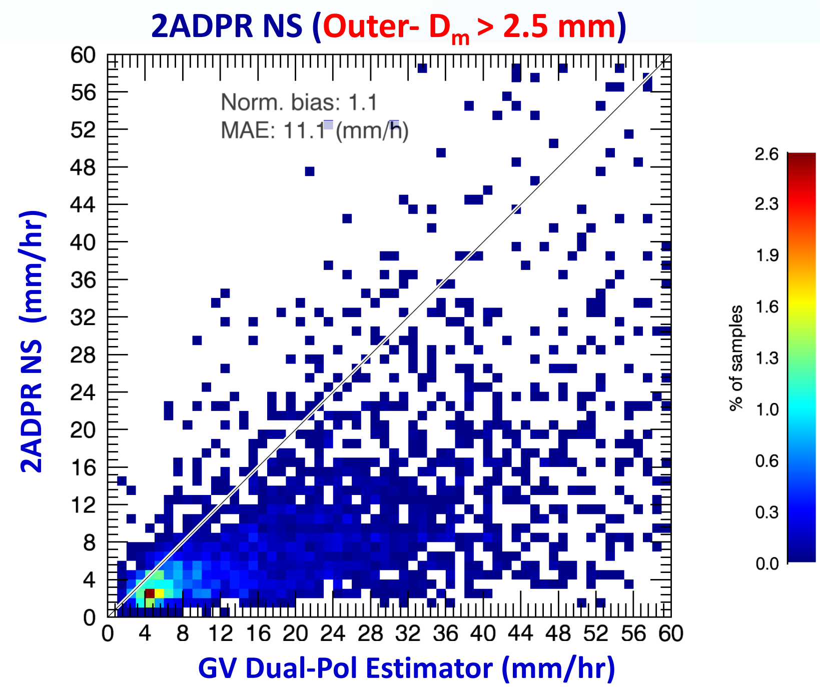
Smaller sample number but similar behavior in Brazil S-band radars

- DPR D_m bias = lower N_w vs GV, but variability along Z-isopleths is similar to GV (radar and 2DVD)

Impacts of Increasingly Positive D_m Bias in Convective Rain

Marked low bias against GV rain rates when DPR-Identified large drop regimes occur

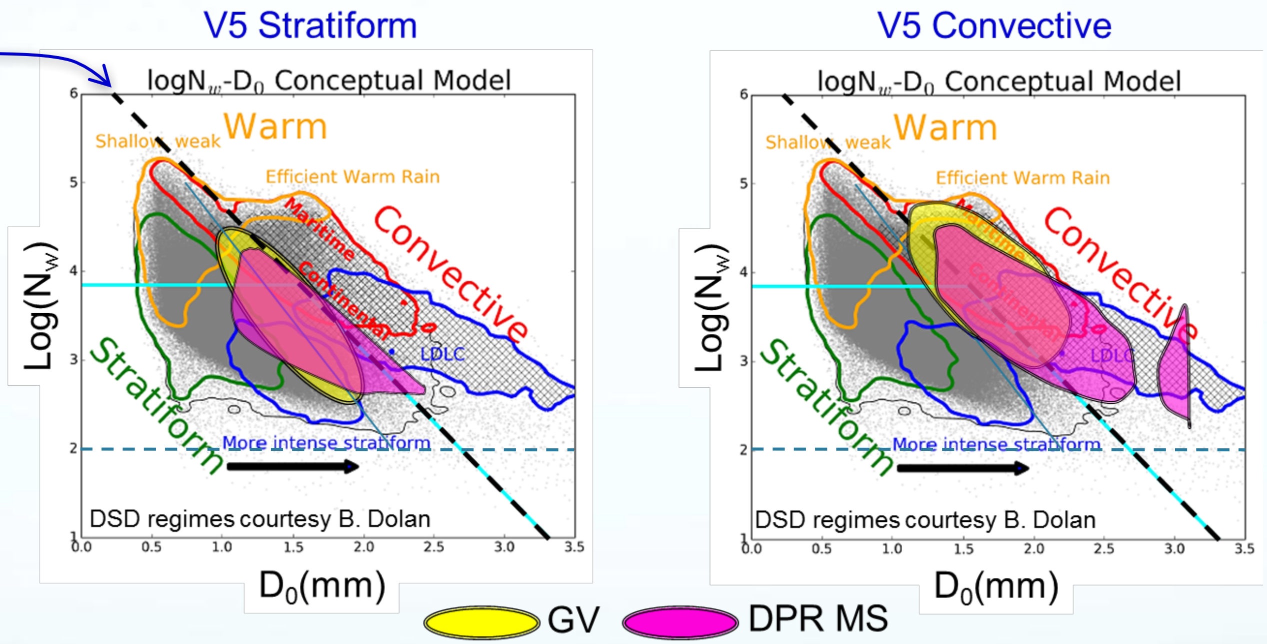




Only 10-20% of total sample, impacts one arm of the much larger DPR-GV comparison scatter……but there nonetheless

DPR MS and GV in Disdrometer Space D_m and N_w

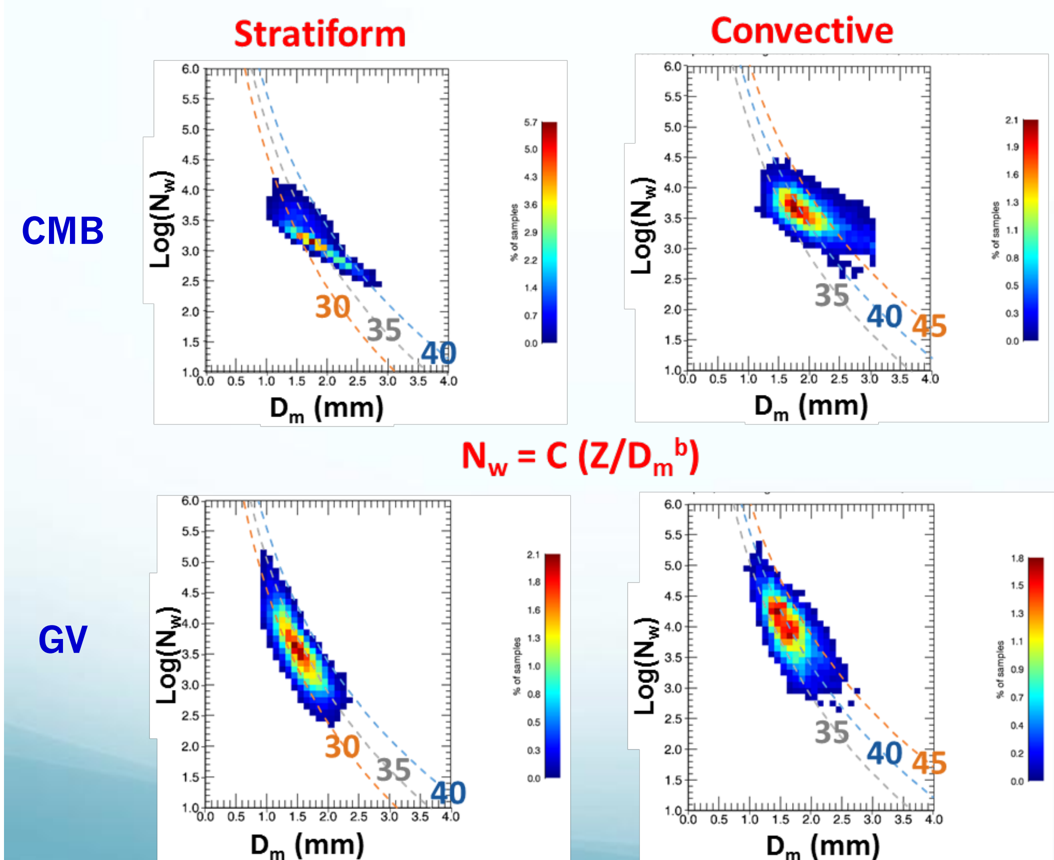
C/S Separation line (e.g., Thompson et al. 2015, Thurai et al., 2015, Bringi et al., 2009)



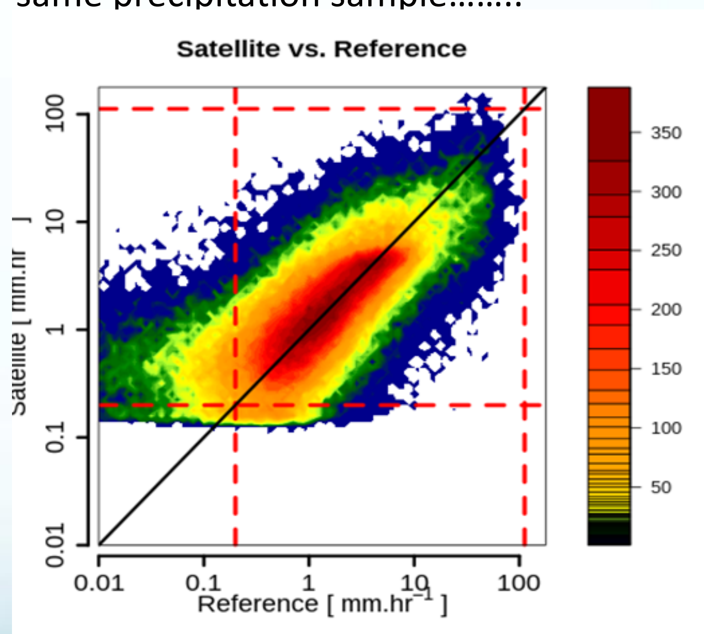
- V5 MS fits GV sample space (*Assuming* $D_m \approx D_0$) physical behavior qualitatively…..though, overlap between C/S exists…………sensitivity to how C/S is partitioned

Also see Dolan et al., 2017, JAS (submitted)

Combined Algorithm: MS Swath with GV (DSD, Rain, Z…)



- N_w vs. $f(D_m,Z)$ trend (slope) is different from GV and DPR for approximately the same precipitation sample……..



- Yet rain rate estimates are pretty robust!

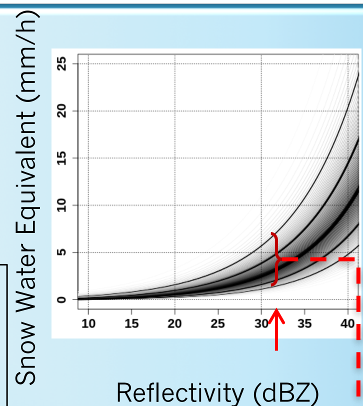
Improving Snow Water Equivalent (SWE) Rate estimates for a "Reference" MRMS L2 and L3 SWE dataset

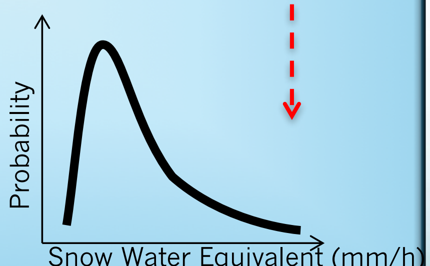
Probabilistic SWE using Radar Observations and Ground Stations

Associate reflectivity and reference SWE with MRMS snow type=3

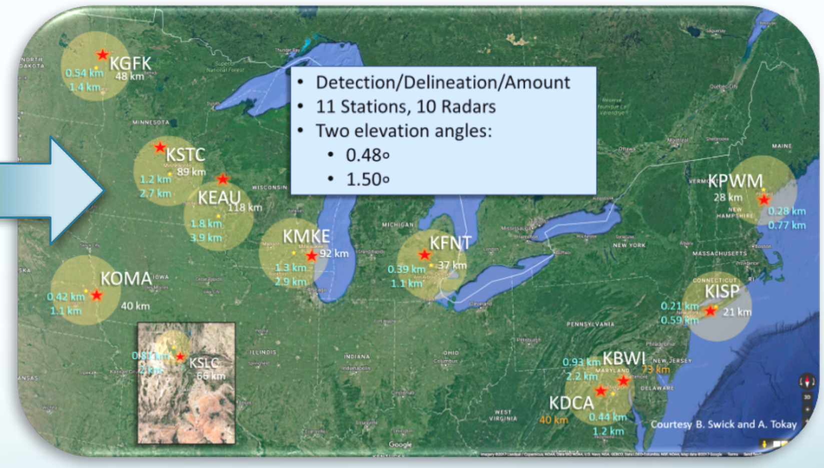
Model distribution of SWE conditioned on reflectivity, temperature and/or radar beam height (other factors possible)

Given 2 min MRMS snow type and reflectivity (+other factors), yields distribution of SWE





Verifying GV-MRMS Probabilistic QPE in L2 (instantaneous) and L3 (30 minute accumulation) Products

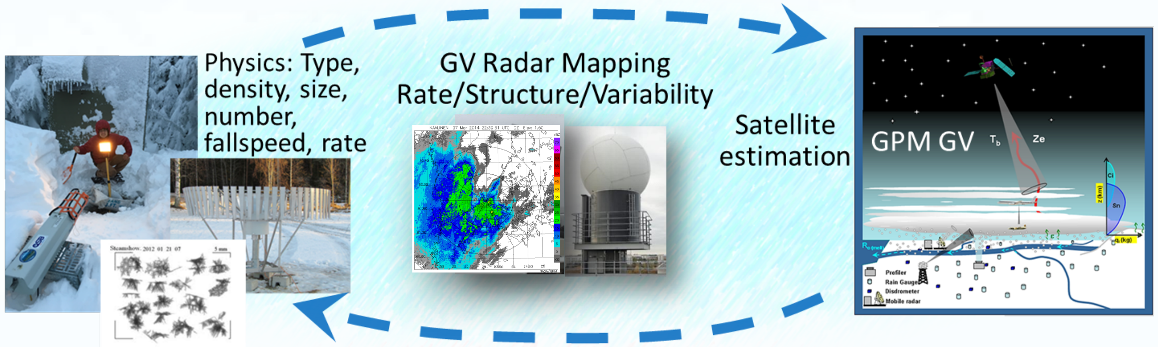


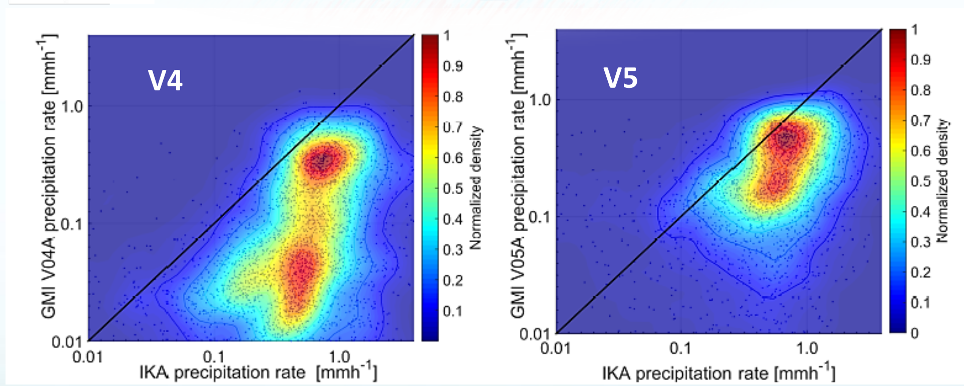
ASOS: Weighing gauges, T_{sfc}, $T_{w,}$ present weather + sounding/model profiles.....

Kirstetter, P.E., J.J. Gourley, Y. Hong, J. Zhang, S. Moazamigoodarzi, C. Langston, A. Arthur, 2015: Probabilistic Precipitation Rate Estimates with Ground-based Radar Networks. *Water Resources Research*, **51**, 1422–1442. doi:10.1002/2014WR015672

Snow Water Equivalent Rates: GMI-GV: Hyytiala Finland Site

Concept:
Case-by-case SWER maps adjusted for dominant snow process, compared to regional network, then used for overpass comparison



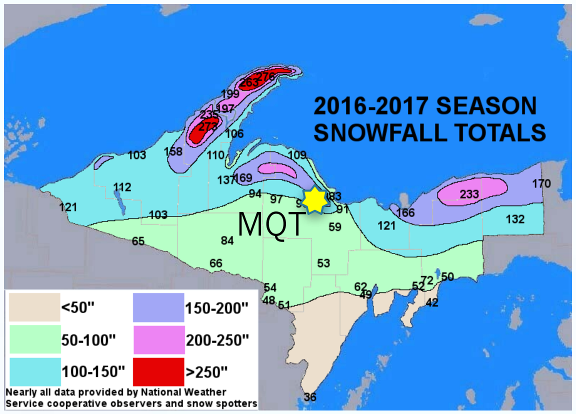


V5 GPROF snowfall improved bias relative to V4 over Finland GV site.

Gridded datasets from Finland overpass subset available: Cf. GPM GV Website

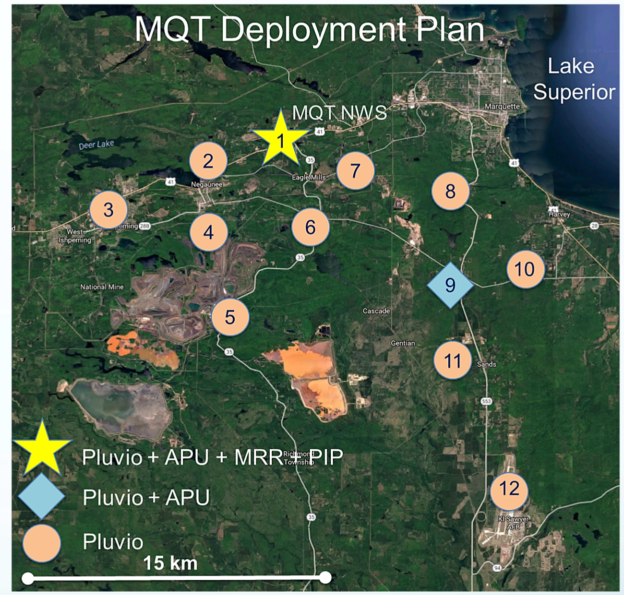
von Lerber et al. 2017, JAMC, submitted

GMI/DPR Footprint Snowfall Variability

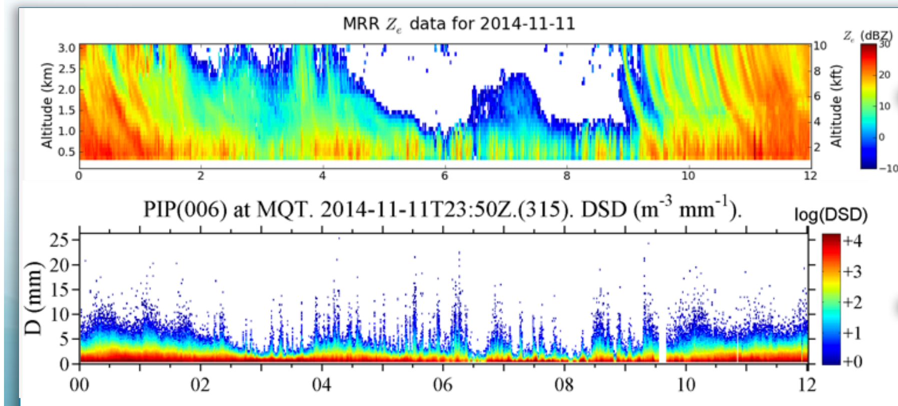


- Partner: Marquette, MI NWS
- 3+ years MRR + PIP observations
- Large annual snowfall amounts
- Different snowfall modes (frontal, lake effect, orographic, combination)

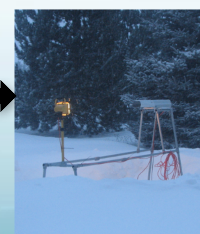
Making a "footprint" Reference



- 12 Pluvio-2, 2 APU (present weather), PIP and MRR
- Attempting winter 17/18 install



Micro Rain Radar (MRR)



Precip. Imaging Package (PIP)

ICE-POP: *International Collaborative Experiment – PyeongChang Olympics-Paralympics 2018*

- **KMA-lead, WMO-sponsored winter precipitation research/forecast demonstration project (Jan-Mar. 2018)**
- **Main Objective: Improve understanding and prediction of orographic falling snow**

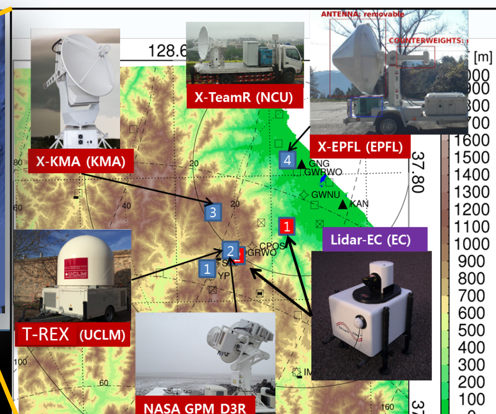
<u>NASA Objective(s):</u> Collaborate with interagency/international partners to:

- Evaluate and Improve GPM estimates of orographic snow
- Test and improve NWP, cloud model orographic snow physics
- Serve/test new satellite products in decision support environment

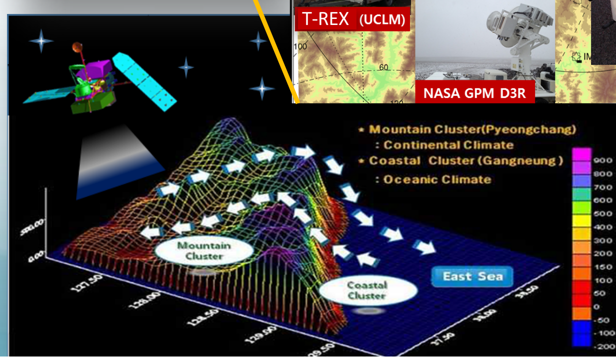
<u>NASA Contributions:</u>

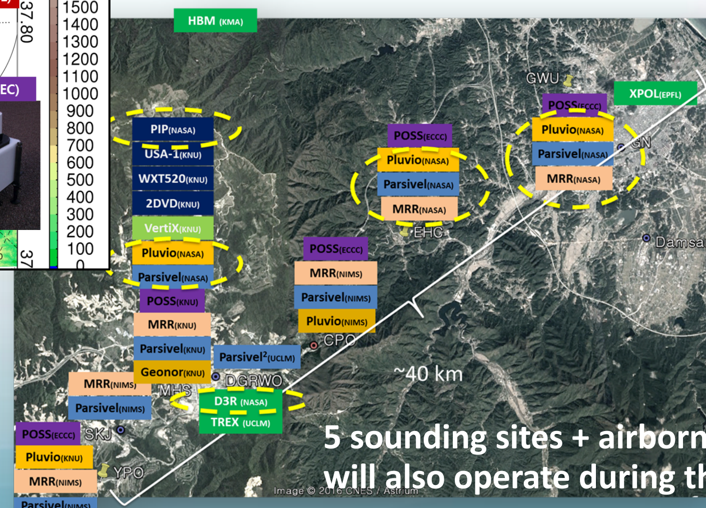
- <u>Instruments</u>- D3R, MRRs, PIPS, Pluvios, Parsivels
- <u>SPoRT</u> GPM products (including NRT surface SH/LH fluxes)
- <u>NU-WRF</u> model forecasts/research

Coast to mountain SW-NE instrument transect/clusters



Addressing larger synoptic scale cyclone and cold-air northeasterly ocean-mountain snow events



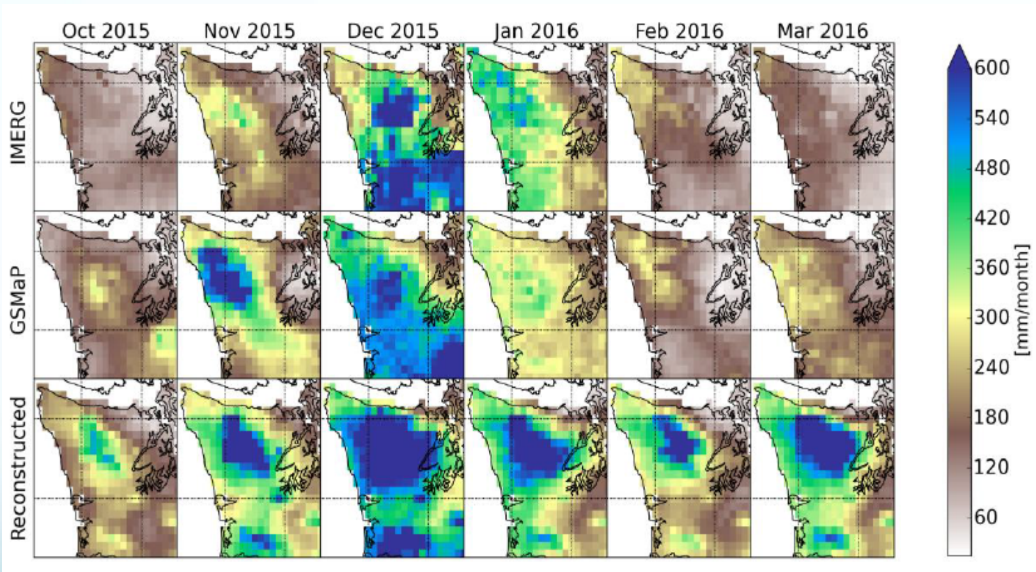


5 sounding sites + airborne dropsondes will also operate during the IOP

Orographic Seasonal Precipitation: Verifying Multi-Sat. Estimates

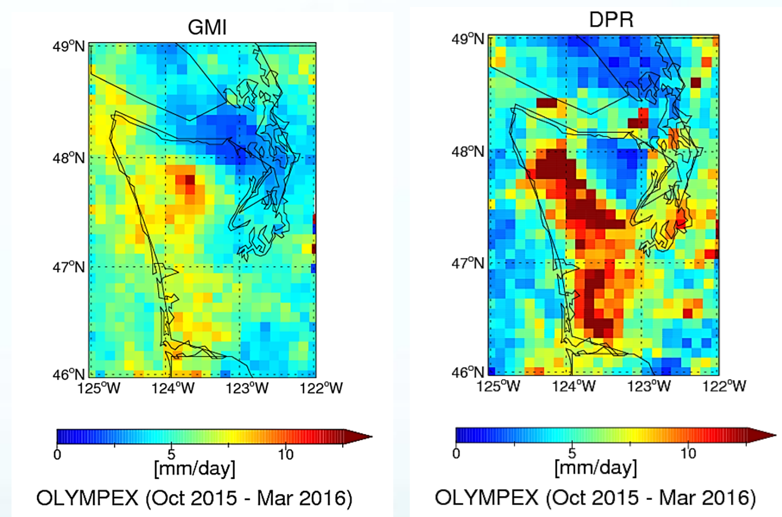
Create a "best" estimate: Combine OLYMPEX [gauges], regional gauges, SNOTEL, MRMS, MRMS-MM and constrain with ASO and VIC model

Compare to IMERG, GSMAP



Cao et al., 2017, JHM (in press)

GMI, DPR (Oct-Mar. mm/day)

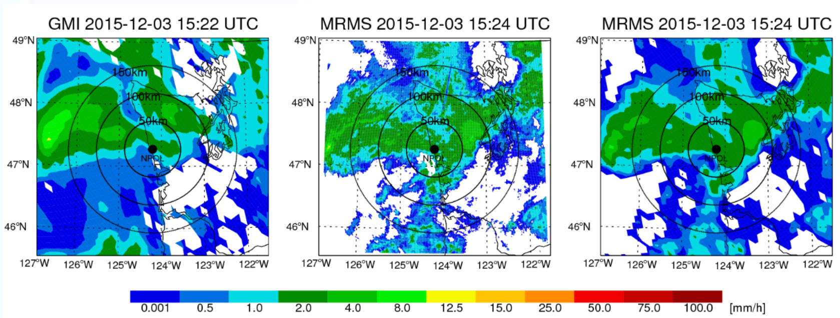


GSMAP low (about 52% of Reconstructed)
IMERG lower (about 43% of Reconstructed)

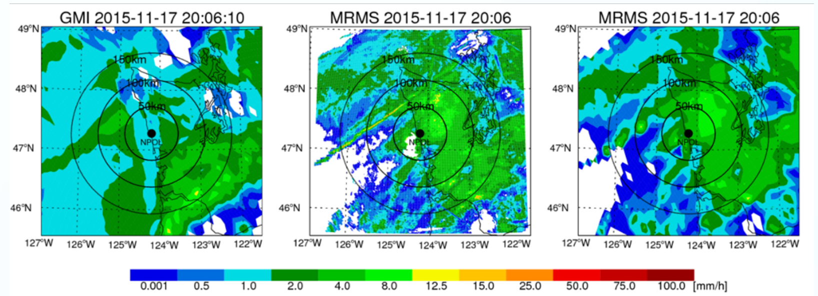
Patterns similar, GMI lowest, DPR closest to reconstructed, but still low "Ballpark"

OLYMPEX Orographic Precipitation Challenges

Pre-Frontal/Warm-Sector mix



Warm-SectorAR and Prefrontal

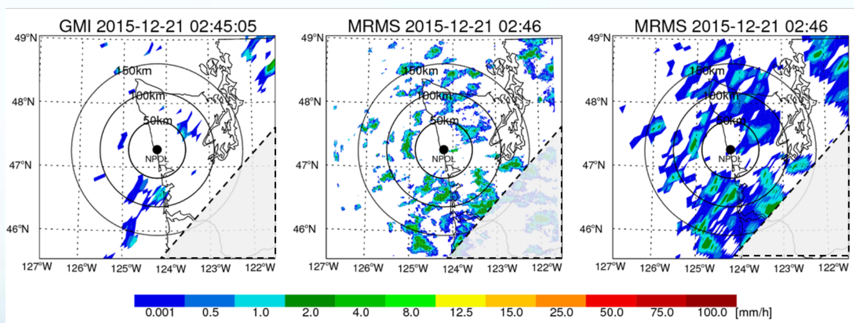


Reasonably good!

Challenge at coastline and into higher terrain

GPROF

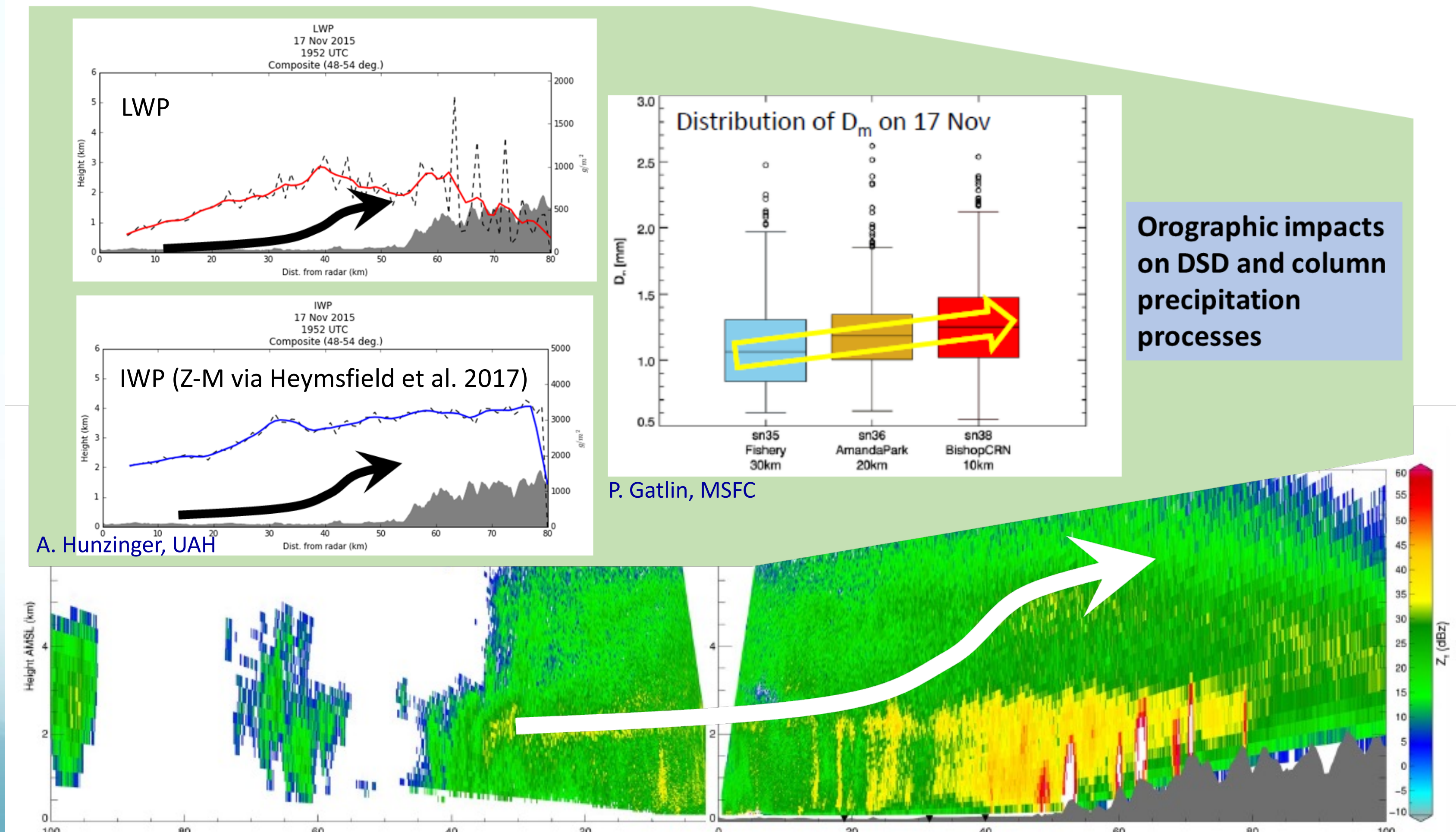
Post frontal



We are often, but not always in the "ballpark"

Challenge of smaller precipitation elements

OLYMPEX Orographic Precipitation Process



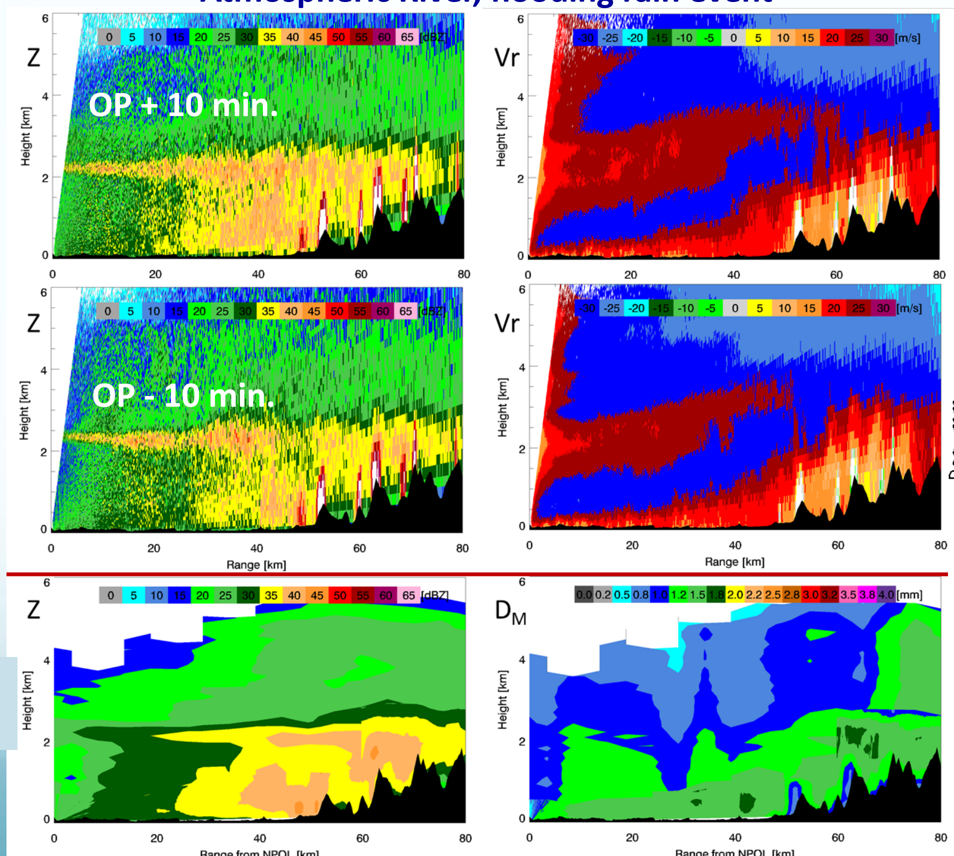
OLYMPEX Orographic Field Campaign Challenges: Profiles

NPOL and DPR 2001 UTC 17 November 2015
Atmospheric River, flooding rain event

NPOL RHI

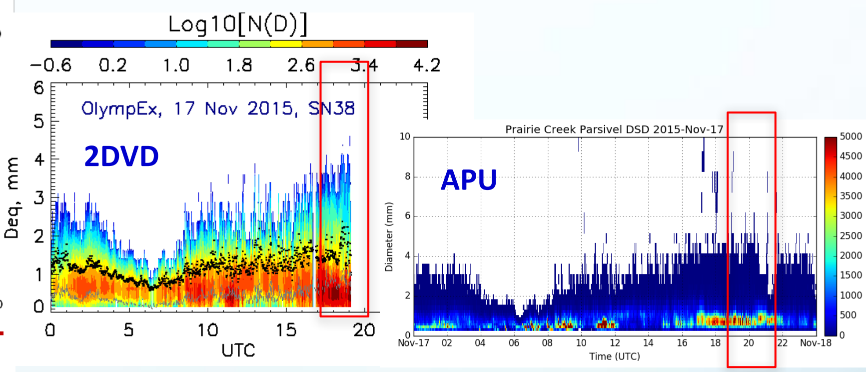
NPOL RHI

DPR +NPOL



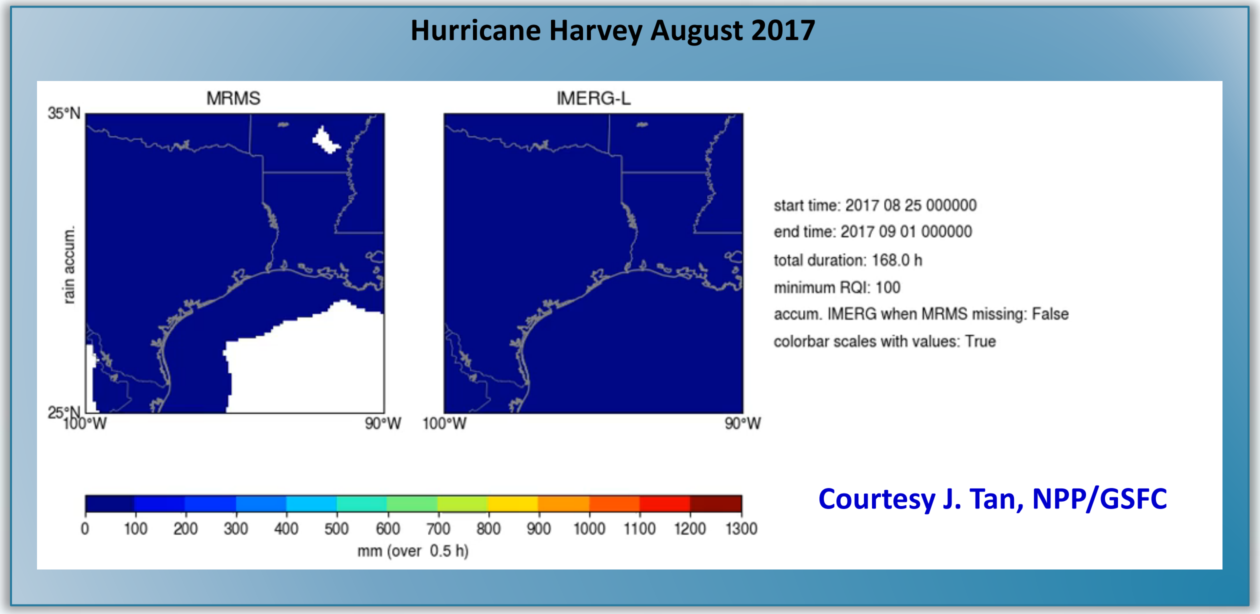
An Important part of the rain profile/process in these heavy rain events occurs at elevations (temperatures) not well sampled by the DPR (GMI)

Profile base: Broadening of the DSD through collision-coalescence in forced lift

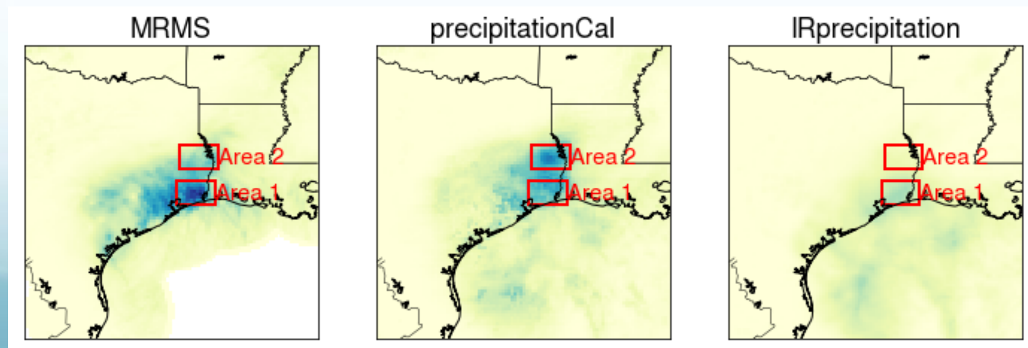


GV "sees" the process- but how do we best exploit the information to "help" algorithms?

IMERG in Hurricane Harvey



Why the error pattern in IMERG?



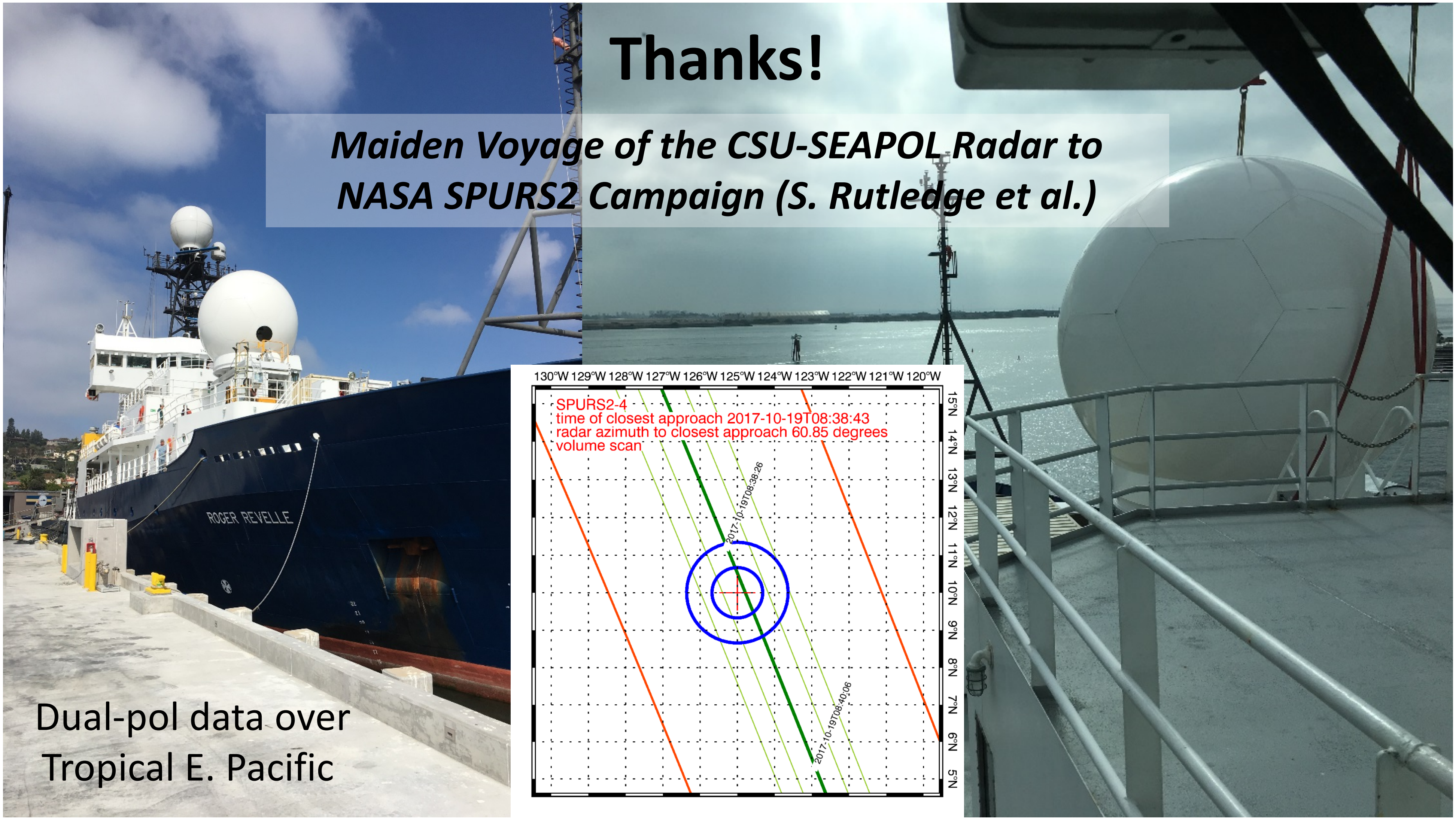
- IR- universally low
- PMW (HQprecip)- low at coast (area-1), high inland (area-2)
- Combination drives error pattern

Summary

- Level 1 requirements satisfied using select CONUS data…..however, exploration of high quality data from other locations is also needed- where do/don't things work (and why)?

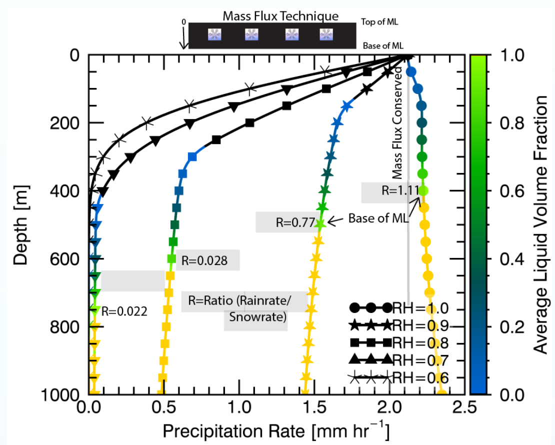
- Extended mission and slower cadence to algorithm version updates permits more GV field and supporting dataset analysis with anticipated impact to algorithms

- Themes for extended mission:
  - Globally-diverse, but *carefully considered*, *reference* precipitation datasets
  - GV field data and analysis of profile physics for algorithms
  - Improved snow water equivalent estimation (ground and aloft)- datasets for algorithm benchmarks
  - Orographic precipitation- benchmark datasets, processes relevant to satellite algorithms
  - IMERG validation- broaden effort, establish a suite of core statistics/approaches for routine and timely monitoring

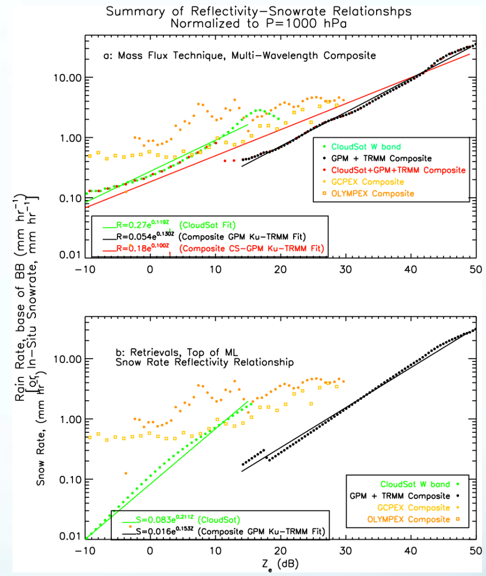

Thanks!
Maiden Voyage of the CSU-SEAPOL Radar to NASA SPURS2 Campaign (S. Rutledge et al.)
ROGER REVELLE
130°W 129°W 128°W 127°W 126°W 125°W 124°W 123°W 122°W 121°W 120°W
15°N 14°N 13°N 12°N 11°N 10°N 9°N 8°N 7°N 6°N 5°N
SPURS2-4
time of closest approach 2017-10-19T08:38:43
radar azimuth to closest approach 60.85 degrees
volume scan
2017-10-19T08:38:26
2017-10-19T08:40:06
Dual-pol data over Tropical E. Pacific

Testing Snowfall Rate Relationships Using Airborne Field Observations OLYMPEX and GCPEX

- Composite ice water content and snowfall rate relationships developed for W, Ka and Ku bands
    - *direct (OLYMPEX and GCPEX in situ microphysical + airborne radar collocation*)
    - Mass flux approaches *(conservation of water mass from top of ML to below ML)* using Z from TRMM, CloudSat and GPM; i.e., W, Ka, Ku bands).
- Mass flux relationships compared most favorably to in situ microphysical data



MF approach sensitive to ML RH- but error estimated < 25%



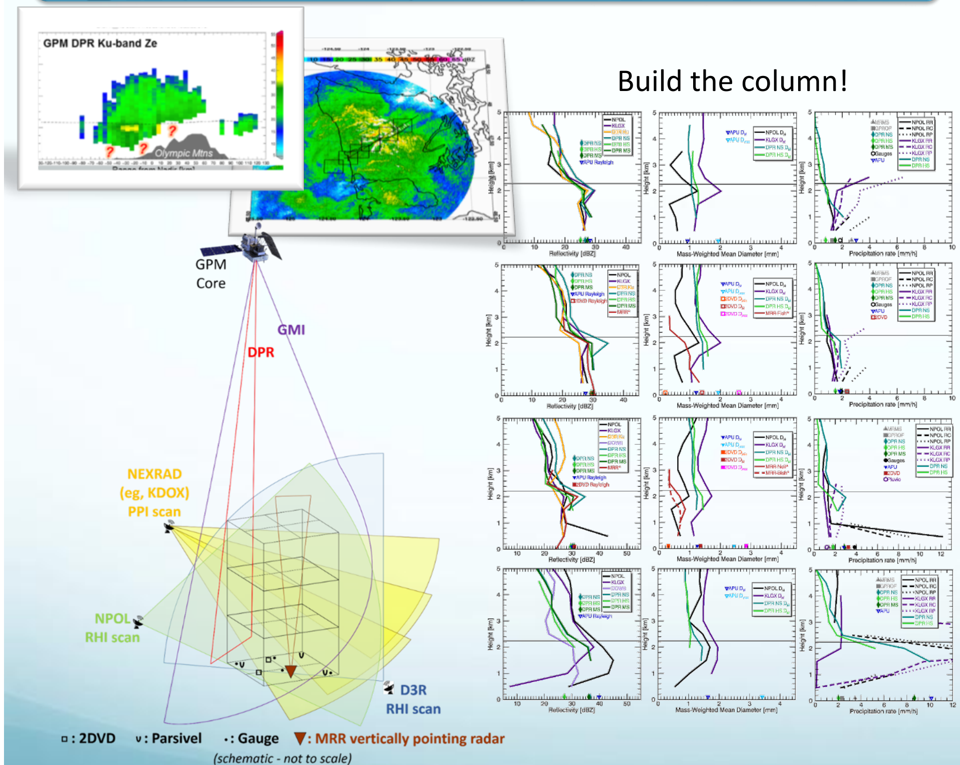
MF approach better represents OLYMPEX and GCPEx observed relationships then satellite-retrievals

Heymsfield et al., 2017, JAS, in press

New Tools and Dataset Mods: Columns for DPR and GPROF

System for Integrating Multi-platform data to Build the Atmospheric Column (SIMBA) Data Fusion Framework

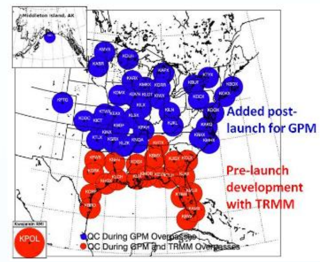
Build the column!

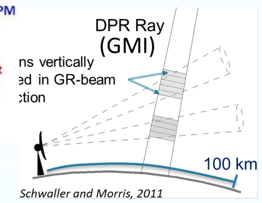


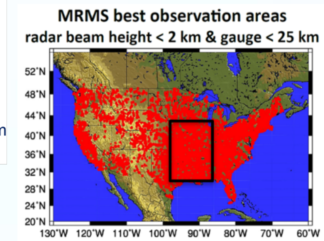
Contact: Stepanie.m.wingo@nasa.gov

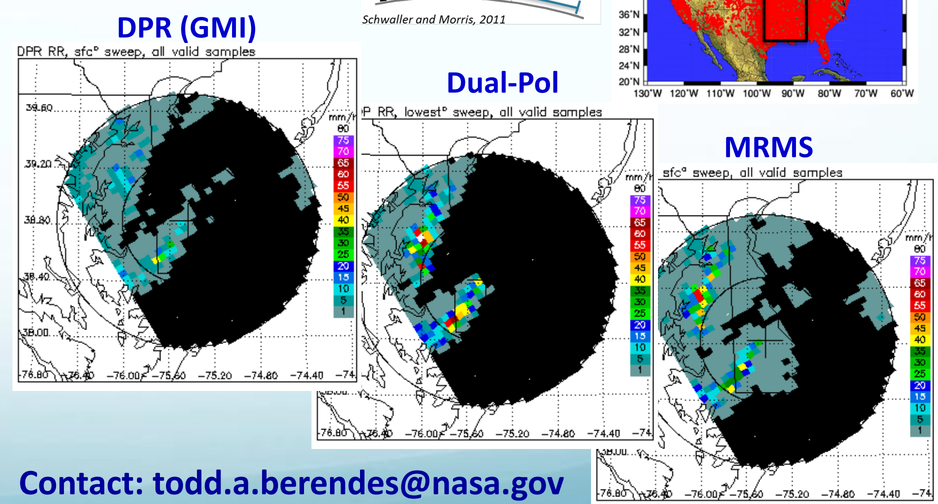
MRMS Merged with Validation Network Dataset

3-D GPM-GV matched rain rates, DSD, HID, dual-pol moments, + MRMS rain characterization









Contact: todd.a.berendes@nasa.gov

Demonstrating 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

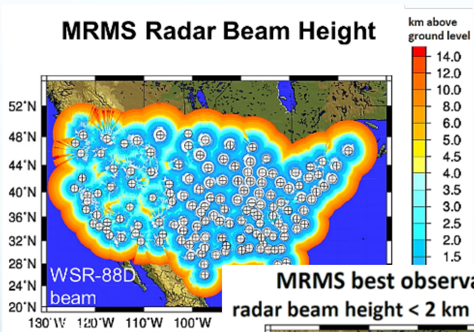
- Detection threshold ~ 0.6 mm/hr for radar and radiometer
- Radar skill delineating rain/snow *at* the surface a bit lower than radiometer- somewhat expected.

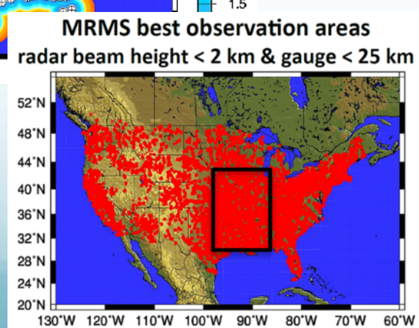
Data

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

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

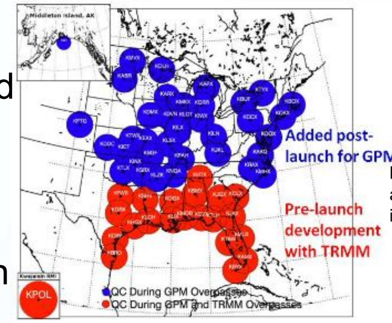
- Gauge bias-corrected radar estimates of precip ***rate and type***
- 0.01° / 2 minute resolution
- Quality-constrained "reference" subsets created

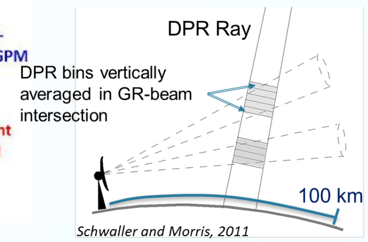




2) Validation Network

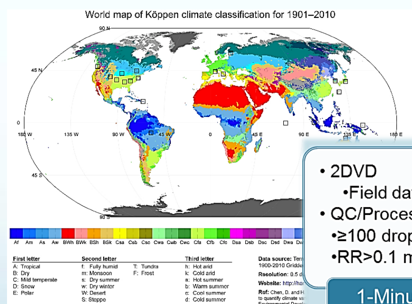
- QC'd 3-D radar volumes and variables geo-matched to DPR sample volumes and GMI footprints
- 65 US + numerous research and international radars

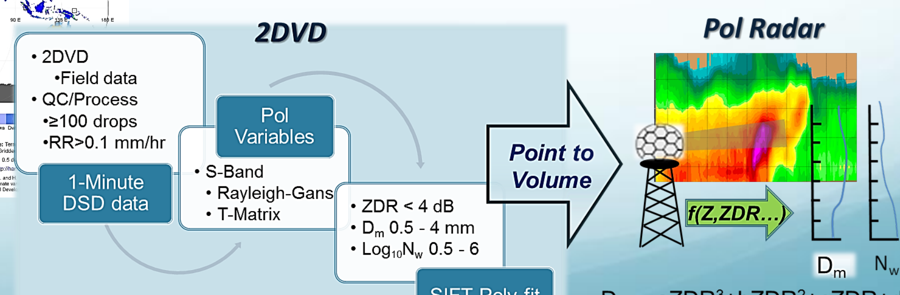




3) Field campaign and Extended Site observations

- Disdrometer sites/network datasets from GPM GV and partners





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

$N_w = aZ^*D_m^b$