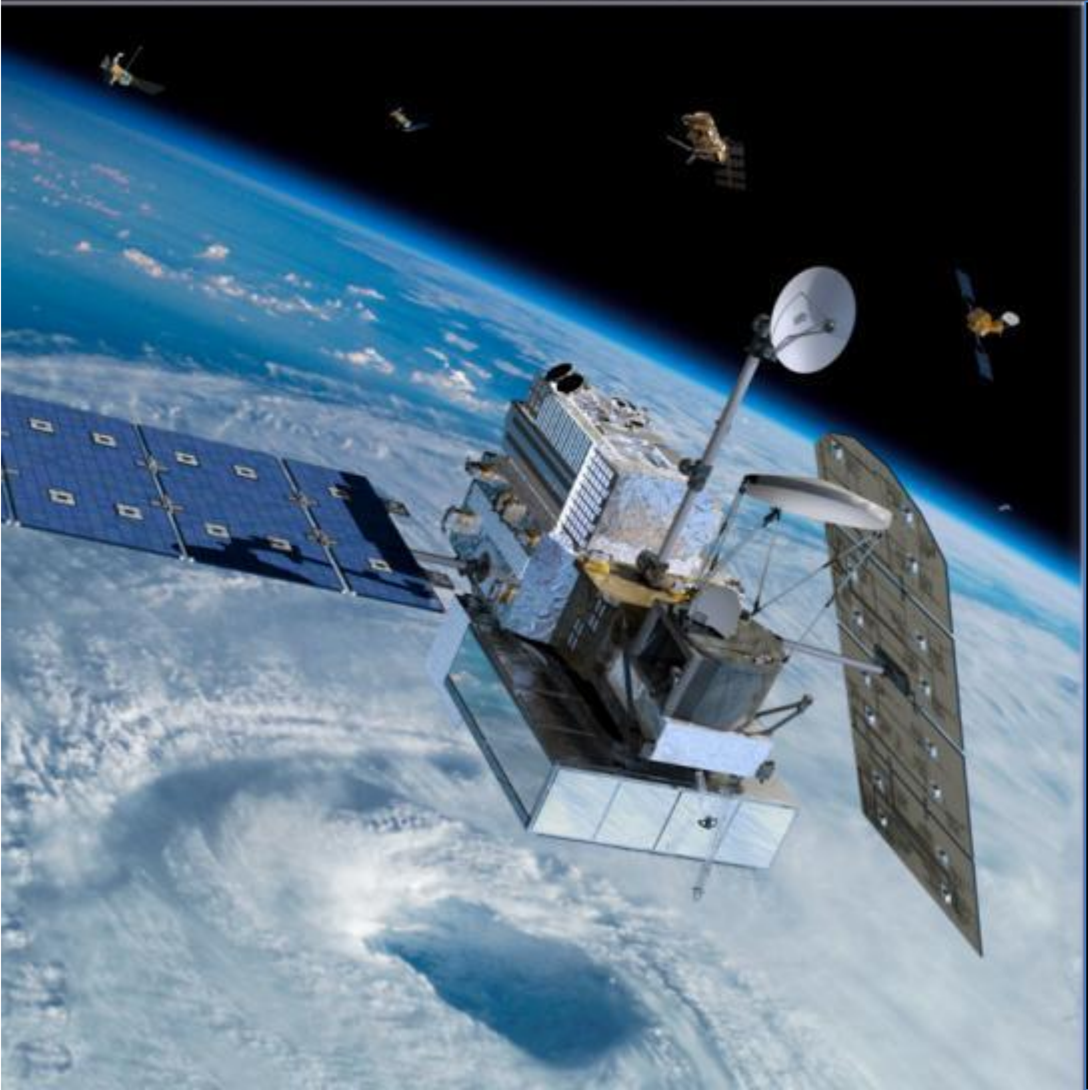
“Core” GV and Science Requirements in the Post-Launch Era



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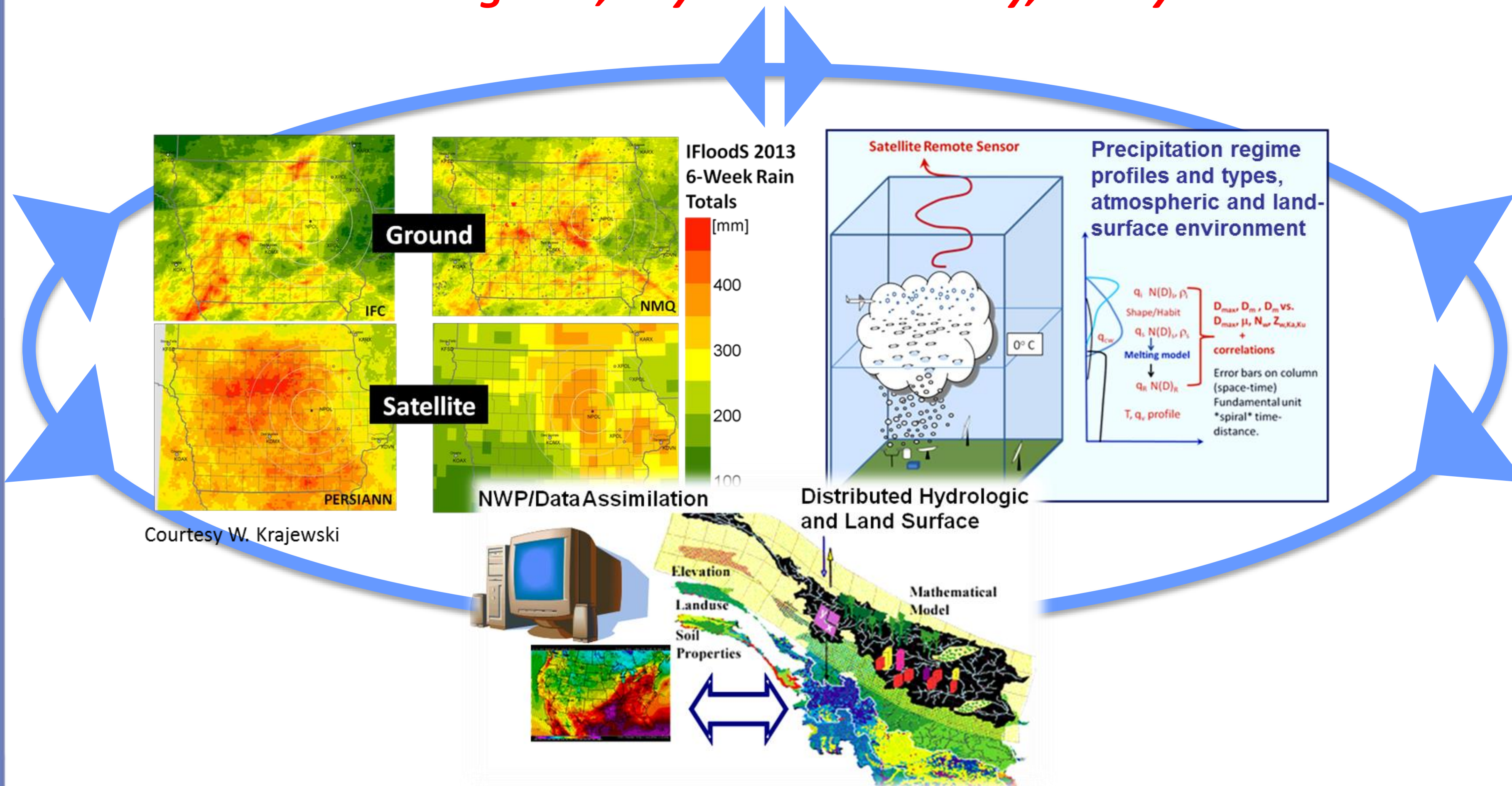
L1 Science Requirements

Continued Science Themes

Acknowledgements: L1 Requirements WG, also P. Kirstetter, J. Wang, D. Wolff, R. Morris, S. Nesbitt, P. Gatlin, J. Tan, D. Moiseev, A. VonLerber

"Core" Science Framework

Convergence, Physical Consistency, Utility

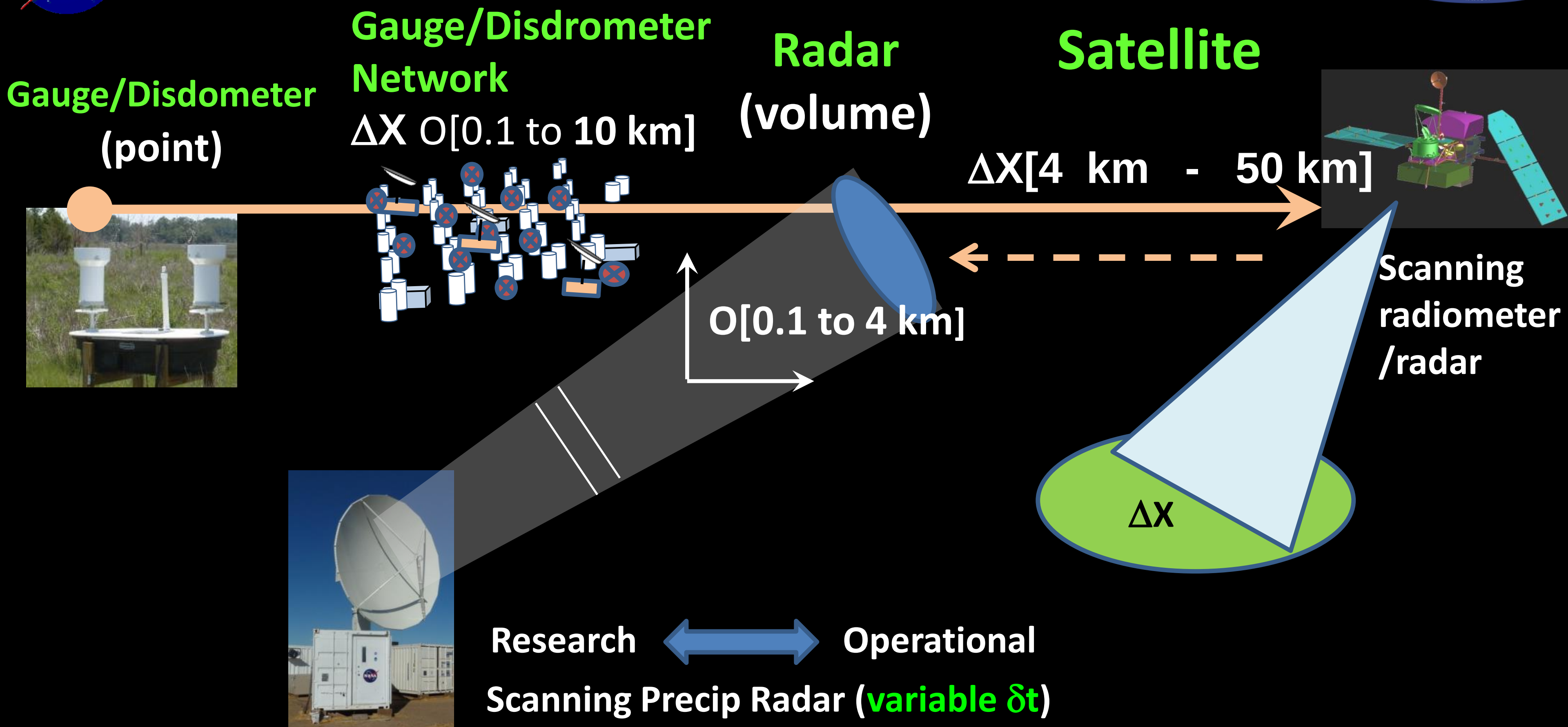


Approaches

- **Direct:** National network comparisons-(Uncertainty- What/Where/When)
- **Physical:** Understand/Assess/improve (algorithm physical assumptions)
- **Integrated:** Impacts/utility with uncertainties (e.g., weather, climate, hydrology)

Measurements are required at a multitude of scales

Radars function as a spatial/temporal "BRIDGE"



- Synergistic and adaptive 4-D use of relevant platforms
  - long term, "heart beat", statistical sampling (national radar network)
  - Ability to "probe" at high space-time res. (research radars)
  - Reference to ground measurements (gauge and disdrometer networks)

GLOBAL PRECIPITATION MEASUREMENT

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 *D_m to within +/- 0.5 mm*.

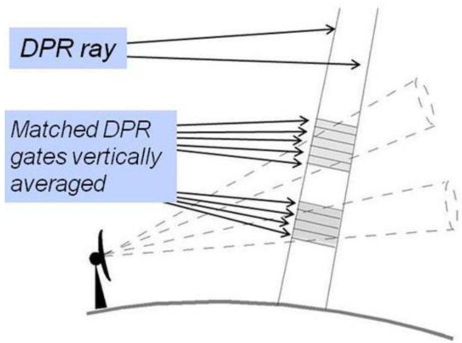
- At 50 km resolution, instantaneous rain rate estimate with *bias and random error < 50% at 1 mm hr^{-1} and < 25% at 10 mm hr^{-1}, relative to calibrated GV*

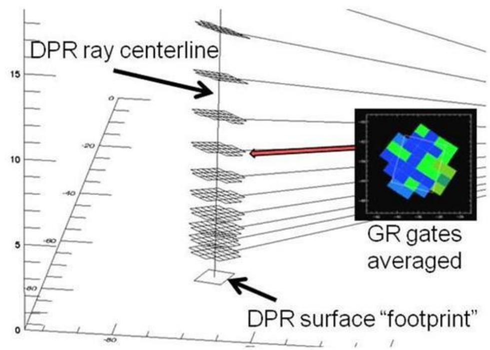
Continental Scale Direct GV Network

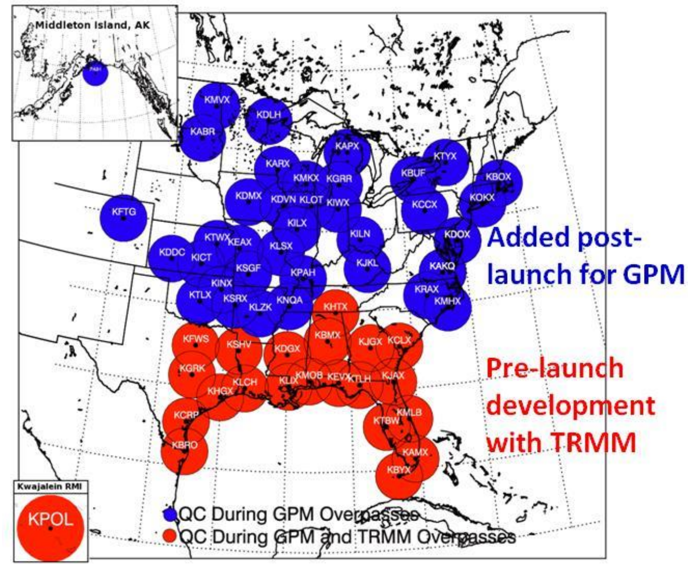
http://gpm-gv.gsfc.nasa.gov/

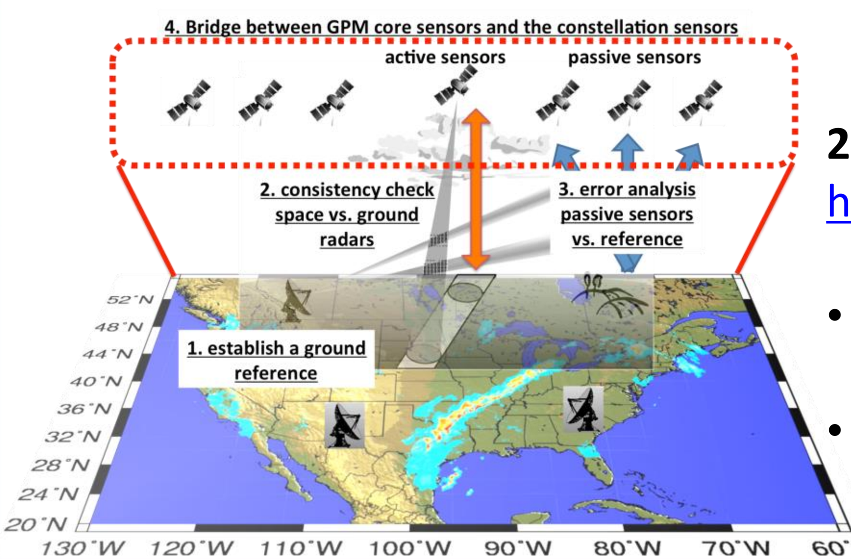
1) Validation Network software creates a radar database (software available)

- ~60 CONUS and international radars geo-matched to DPR and radiometers
- Matched *profiles of ground and satellite-based* Z, rain rate, DSD, HID….









2) NOAA Multi-Radar Multi-Sensor (MRMS)

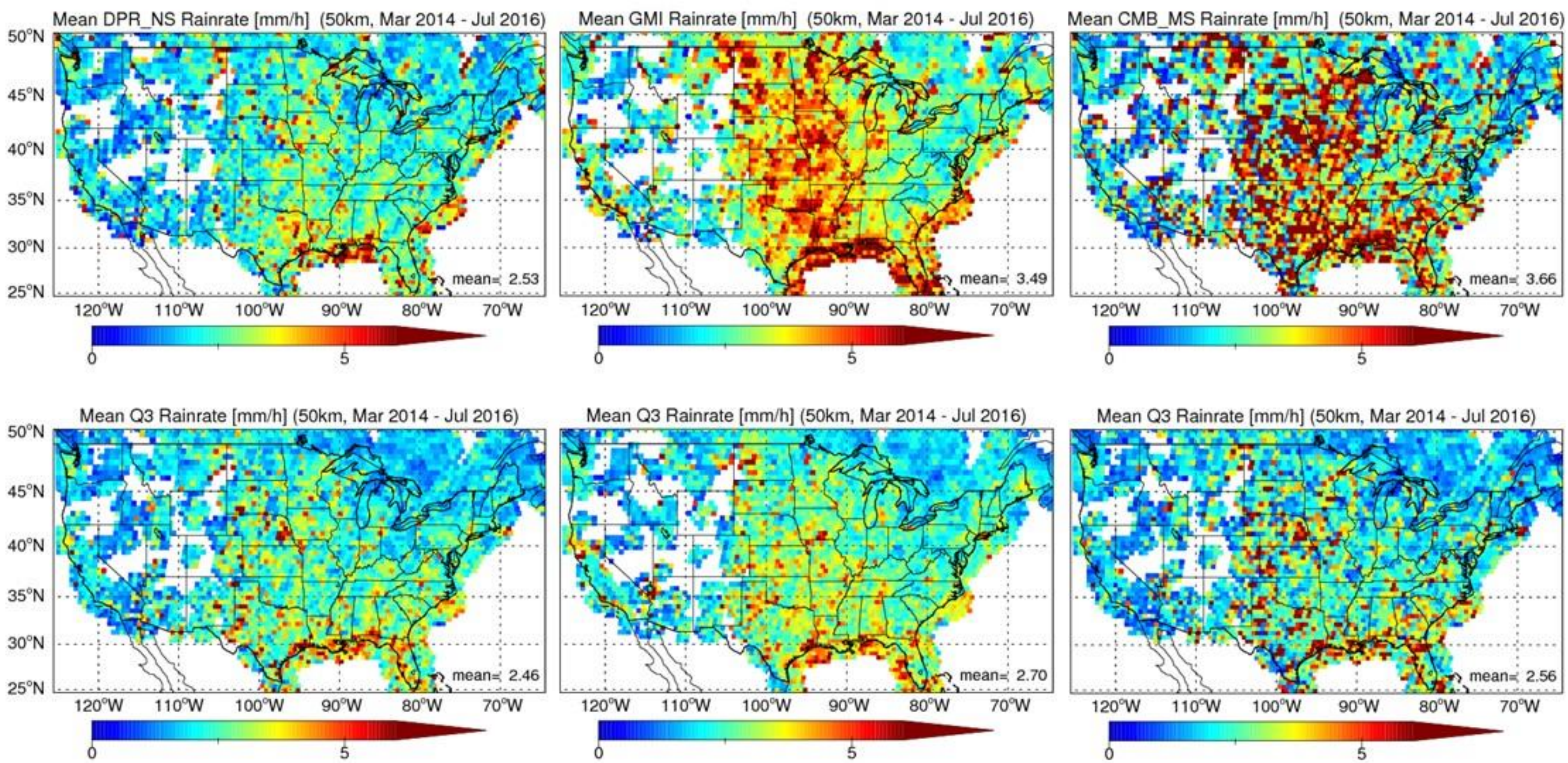
http://nmq.ou.edu/ CONUS- 1-km^2/2 min res.

- Gauge-corrected radar estimates of precip and precip type (liquid, frozen, C/S)
- Orbit coincidence and 30 minute accumulation products with radar quality indices (RQI)

Rain Requirement- BROADER CONTEXT: Land (CONUS) 50 x 50 km

CONUS Mar 14 – July 16: GV MRMS vs. DPR/Combined
Conditioned on 0.2 mm/hr threshold at FOV

DPR NS | GMI-GPROF | Combined MS



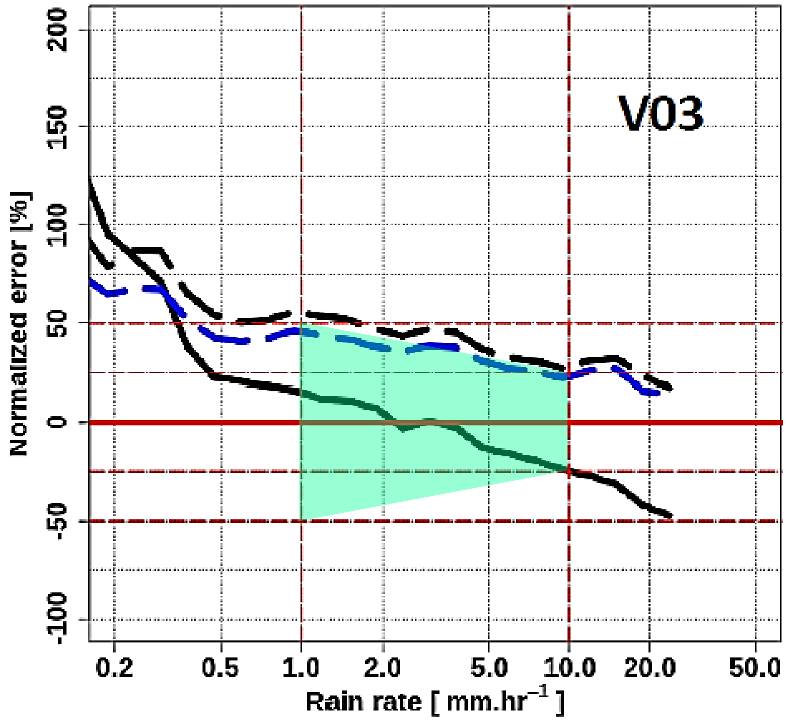
Which products "compare" the best with MRMS? DPR NS (DPR MS and KuPR, similarly)
Relative trends generally consistent with global behavior over land

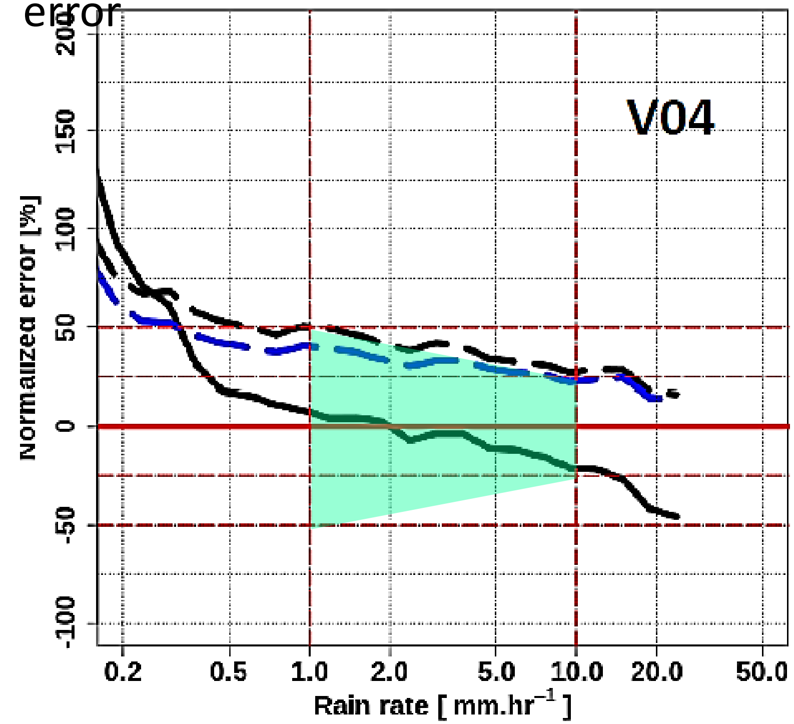
DPR Ku NS V3 vs. V4

L1-Required 50 x 50 km^2 area

(footprint matched, then averaged to 50x 50 km^2)

Need 50%(25%) @ 1 mm/hr (10 mm/hr) bias and random error





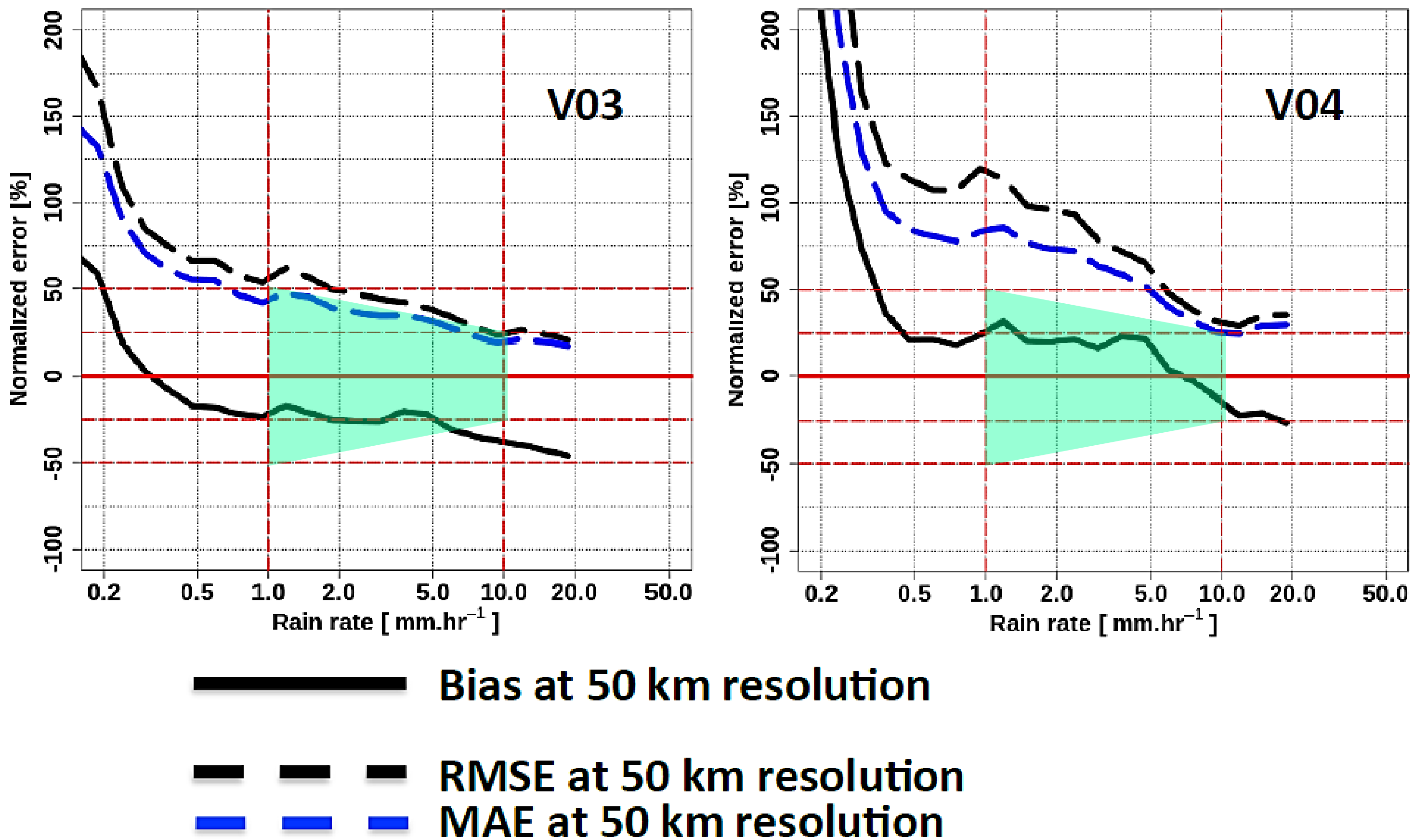
Bias at 50 km resolution

RMSE at 50 km resolution

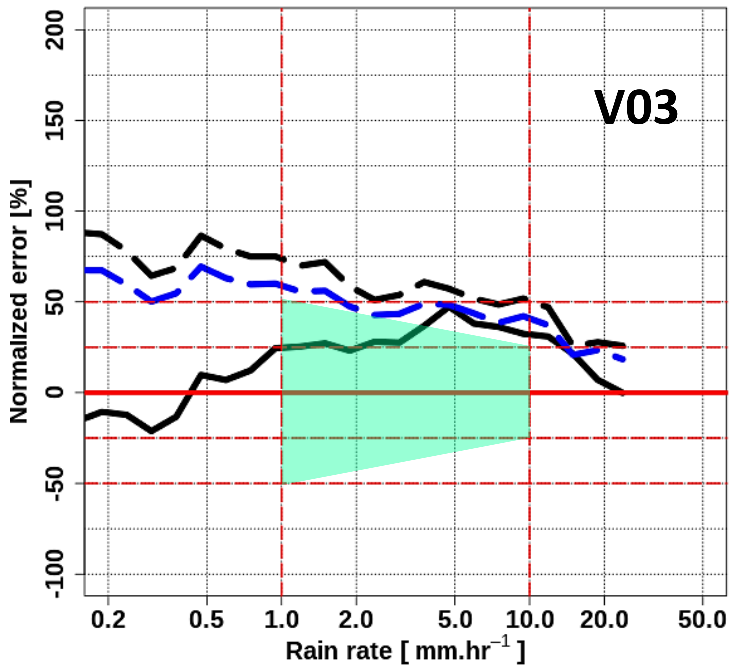
MAE at 50 km resolution

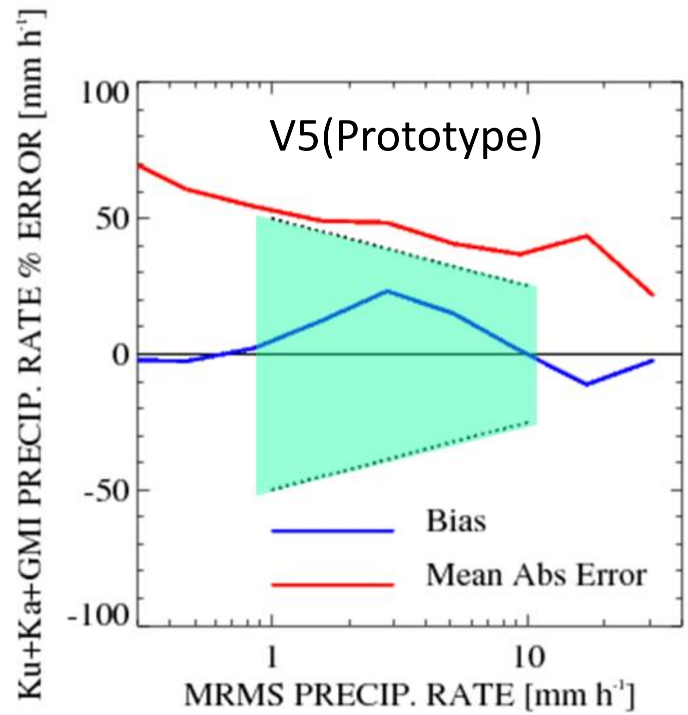
GMI GPROF V3 vs. V4

L1-Required 50 x 50 km^2 area



L1-Required 50 x 50 km^2 area



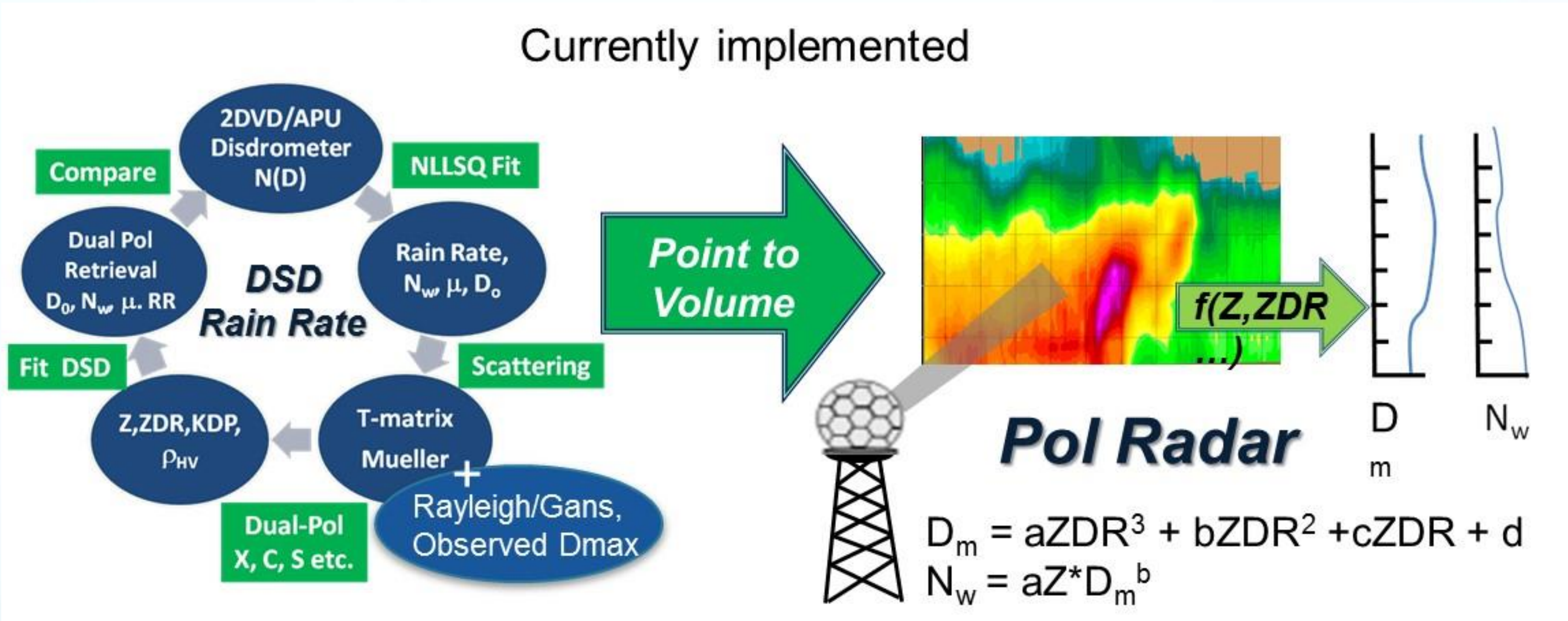


Bias at 50 km resolution

RMSE at 50 km resolution

MAE at 50 km resolution

DSD: GV Disdrometer and Polarimetric Radar



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

$N_w = aZ^*D_m^b$

Minimum D_m ~0.6 mm; Sensitivity of approach at large D_m/ZDR due to limited sample of large drops/high ZDR (also modeling challenge)

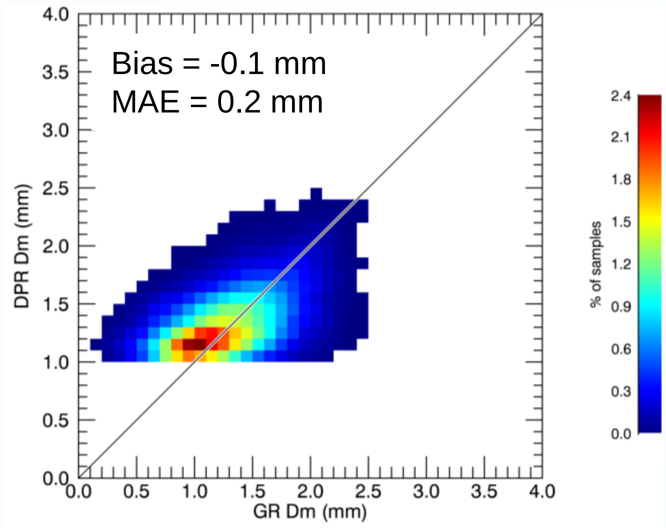
For span of validity, when tested on independent data:
Bias 1 - 10%, MAE 7 -15%

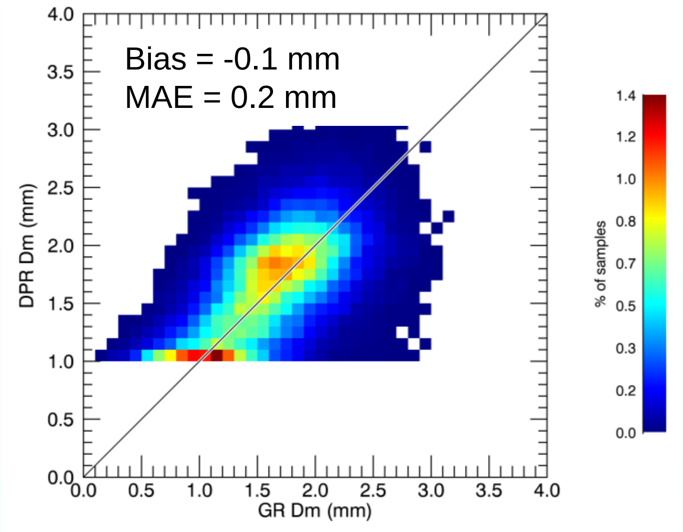
Val. Network GV-DPR matchups for broader view of DPR (NS) D_m

Recall that L1 says "……to within +/- 0.5 mm"……

GV and DPR similar, marked change in convective large D_m mode in V4

V3

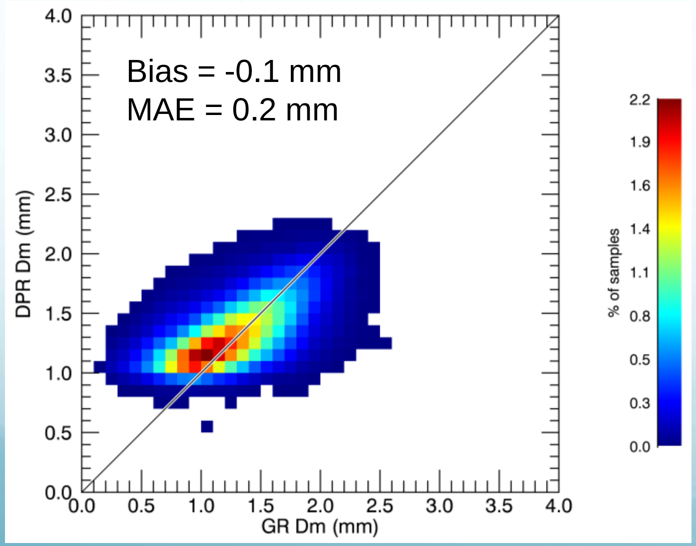


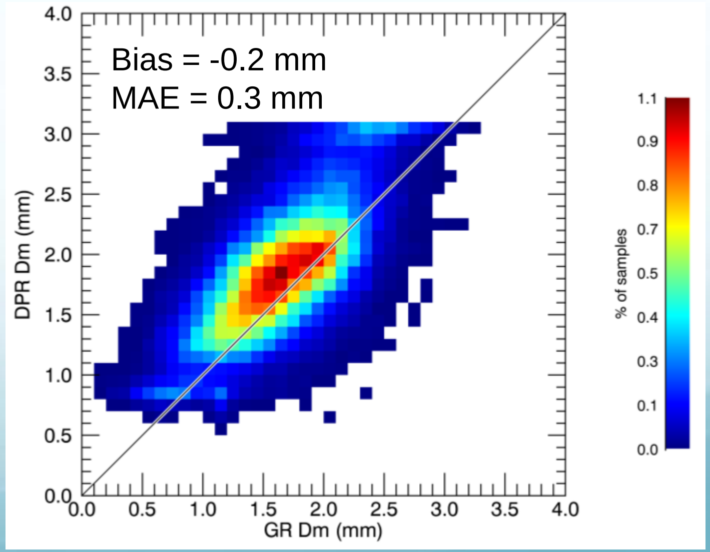


Stratiform

Convective

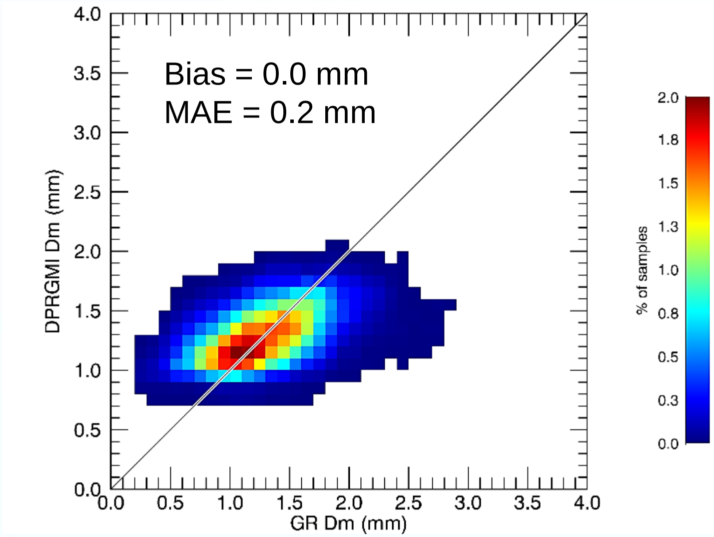
V4

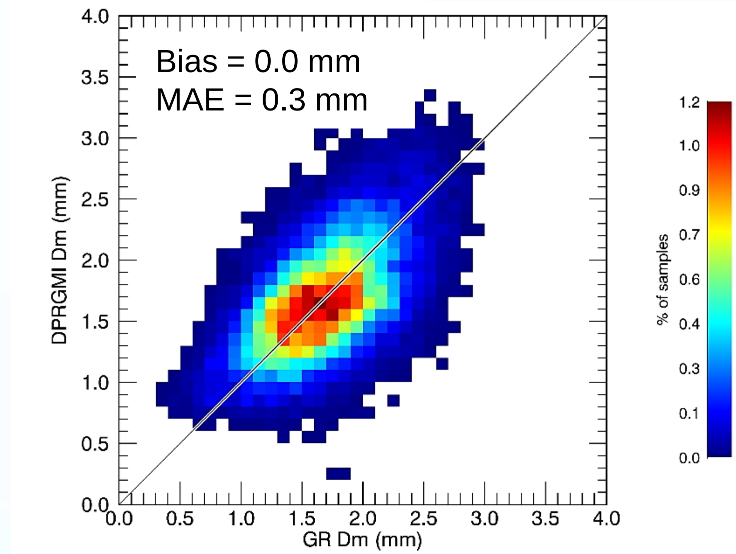




Combined (MS) and GV- good agreement; convective large D_m mode not present…….

V3

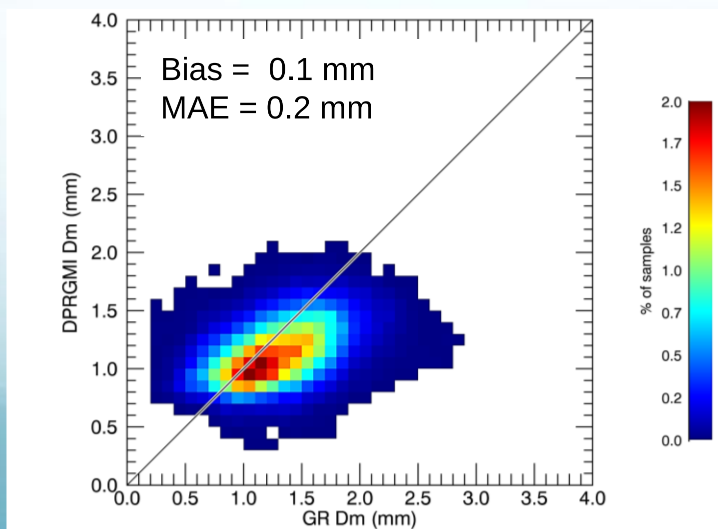


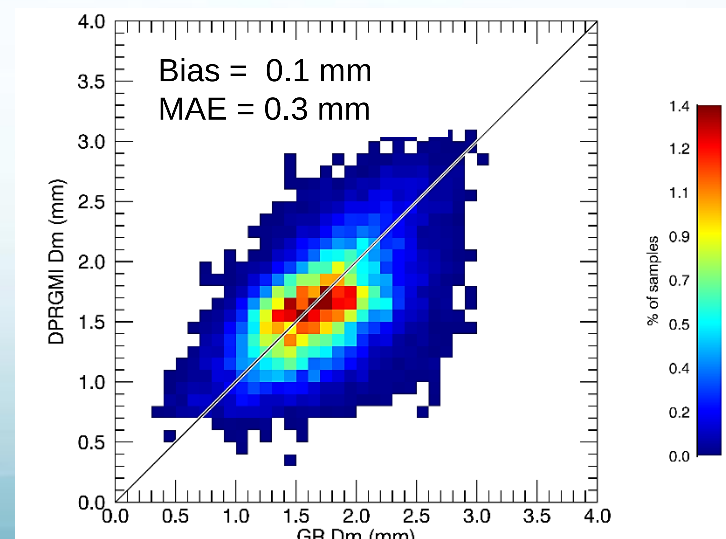


Stratiform

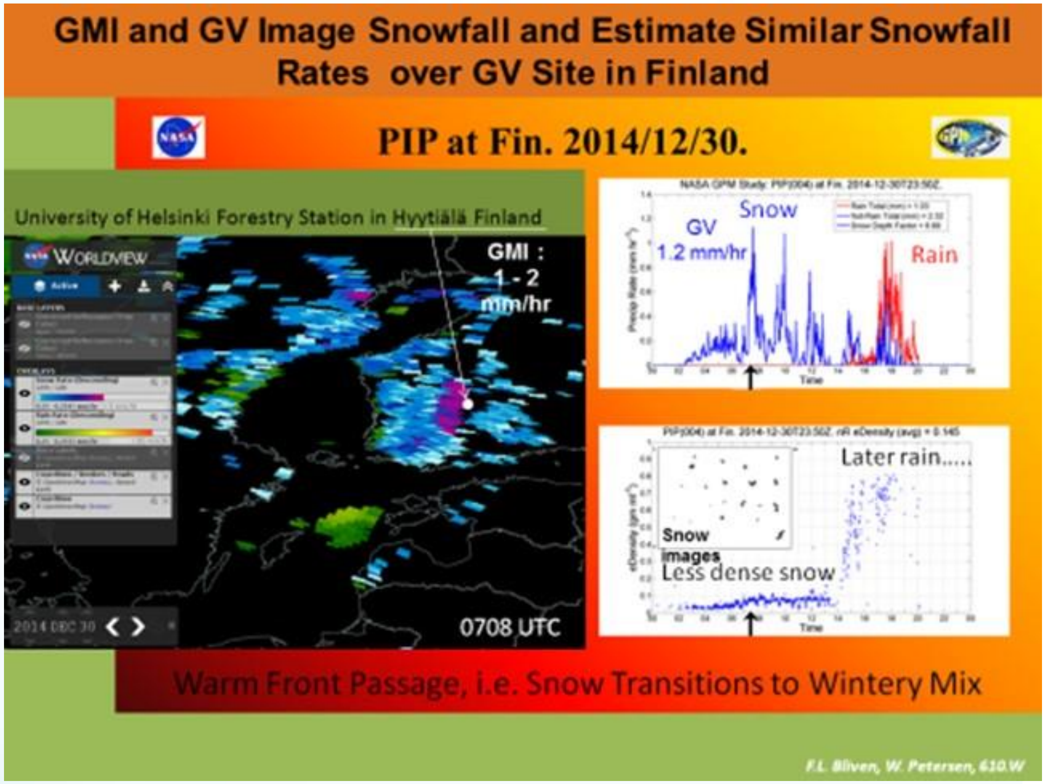
Convective

V4

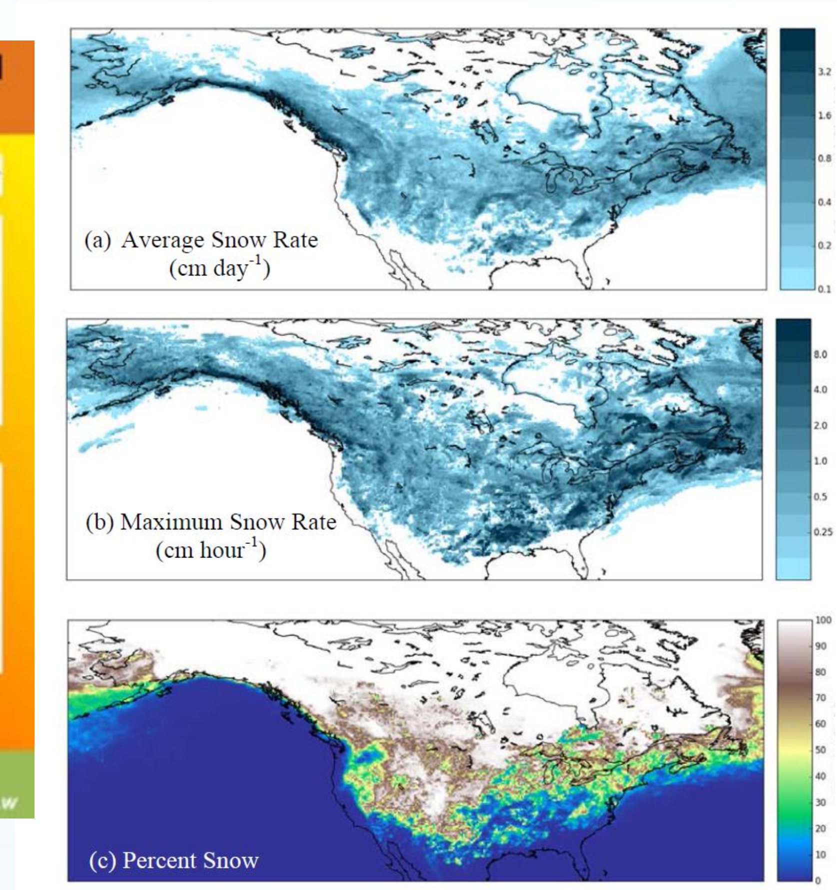




SNOW: “Demonstrate *Detection*” ……



GMI and PIP Instantaneous snowfall rates over Hyytiala, Finland GV site



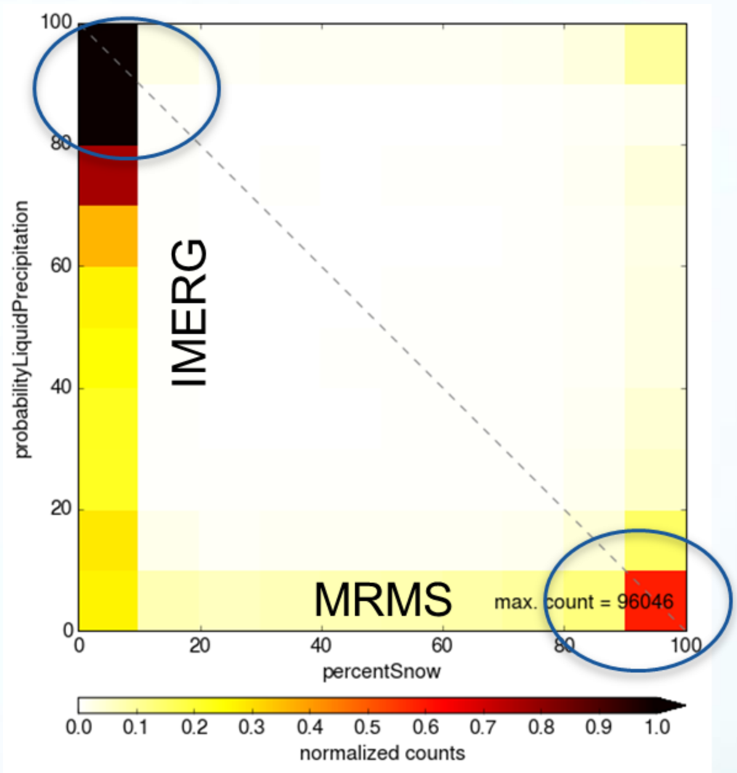
GMI GPROF Seasonal Snow Winter Dec, 2014-Feb. 15

Skofronick-Jackson et al. 2016, submitted

Snow “detection” at FOV: MRMS, Passive Microwave and IR from IMERG

Platform

Snow Detection Land Surface Sensitivity



Snow “detection” is ambiguous….doesn’t define what we do or do not detect”

Mean “miss” SWER based on fixed MRMS Z-S relationship

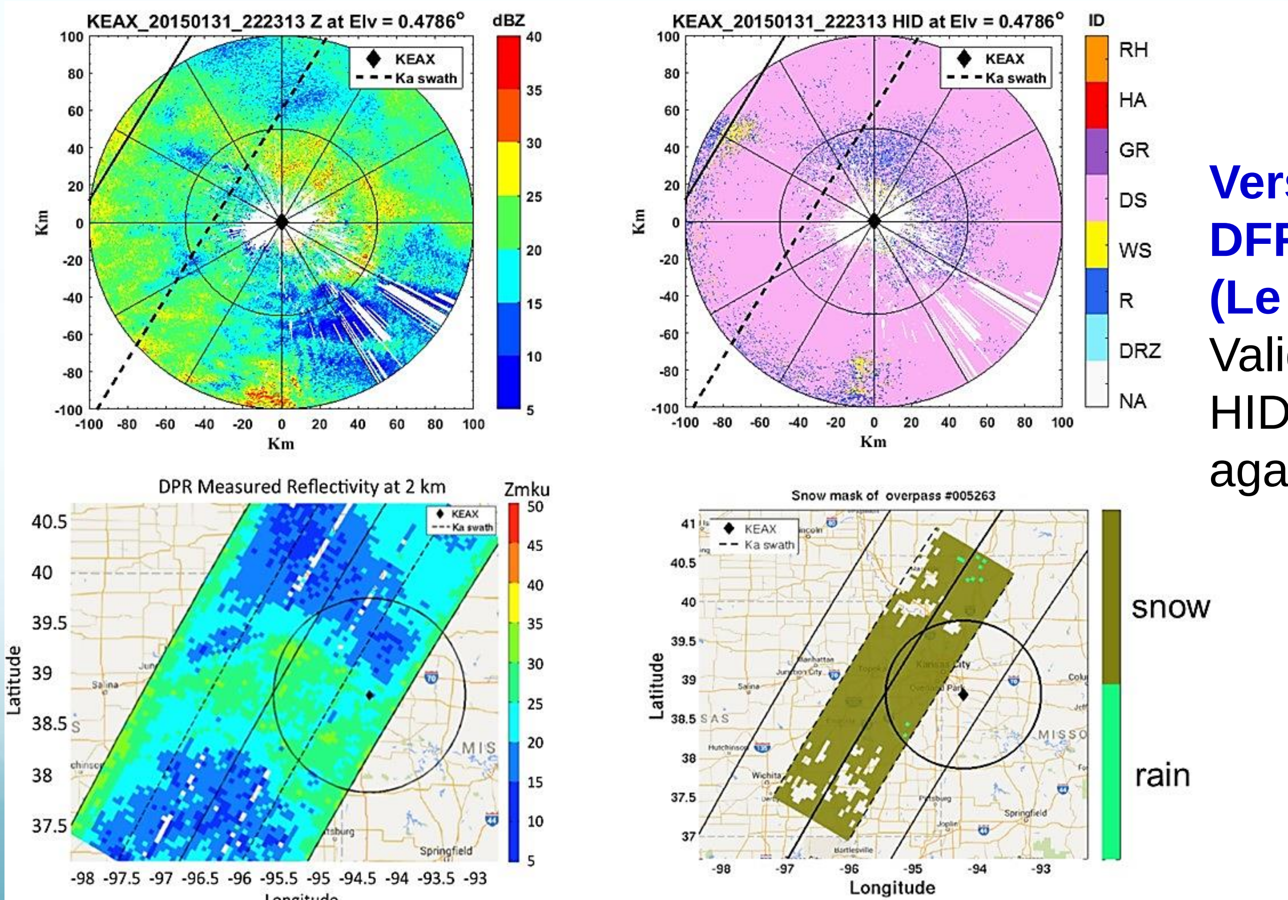
- Land ~1-1.4 mm/hr
- Ocean SWER ~0.57 m/hr

J. Tan

DPR Snow Detection

V4: Precip > 0 for both MRMS and DPR (CMB) MS FOVs, majority of MRMS beam heights < 1.5 km

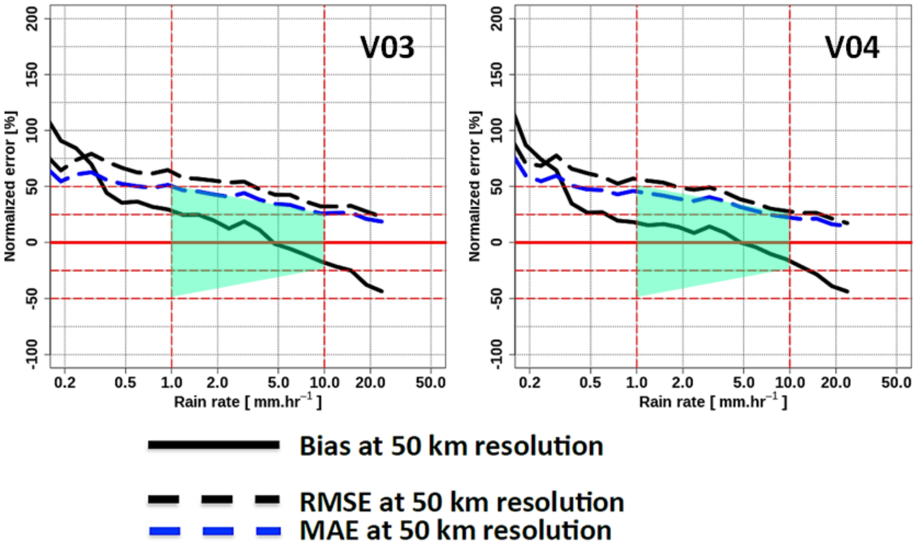
Using PhaseNearSurface (surfLiqRateFrac): POD 87% (89%), FAR 9% (11%)

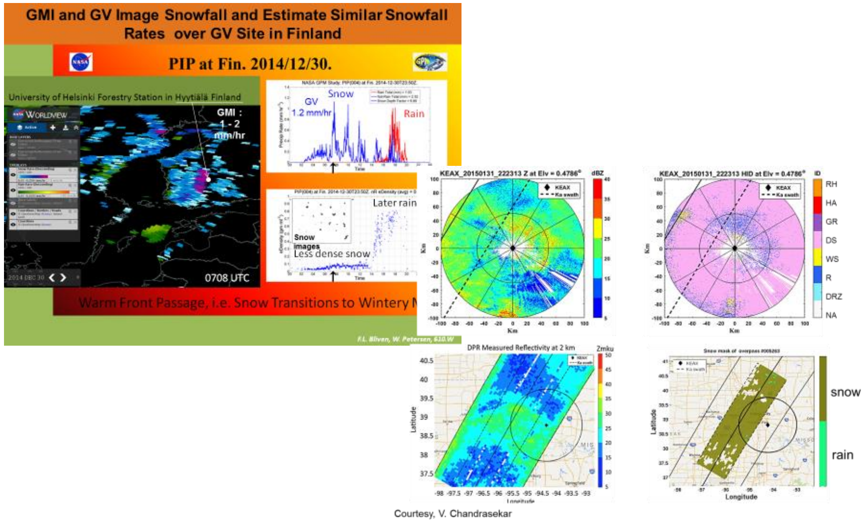


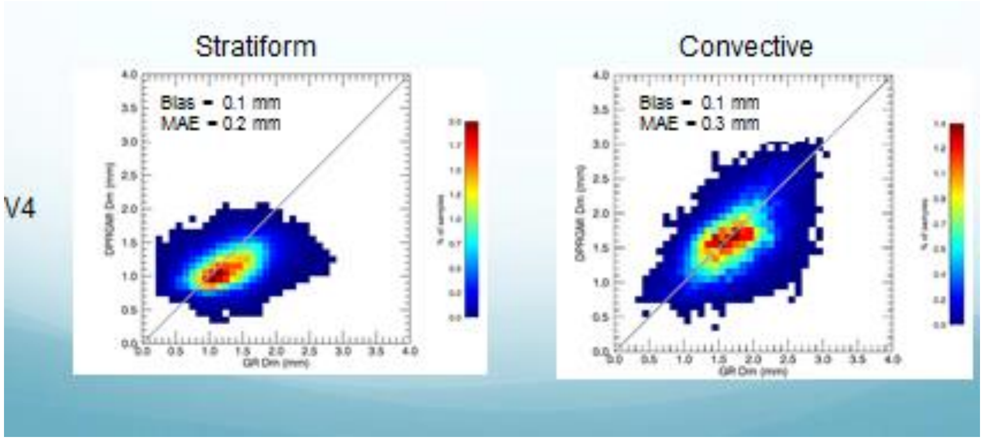
Courtesy, V. Chandrasekar (CSU)

Version 5: New DFRm snow-Index (Le and Chandra):
Validation using 88D HID algorithms against DPR MS

Analysis continues: But we can meet L1 requirements…………



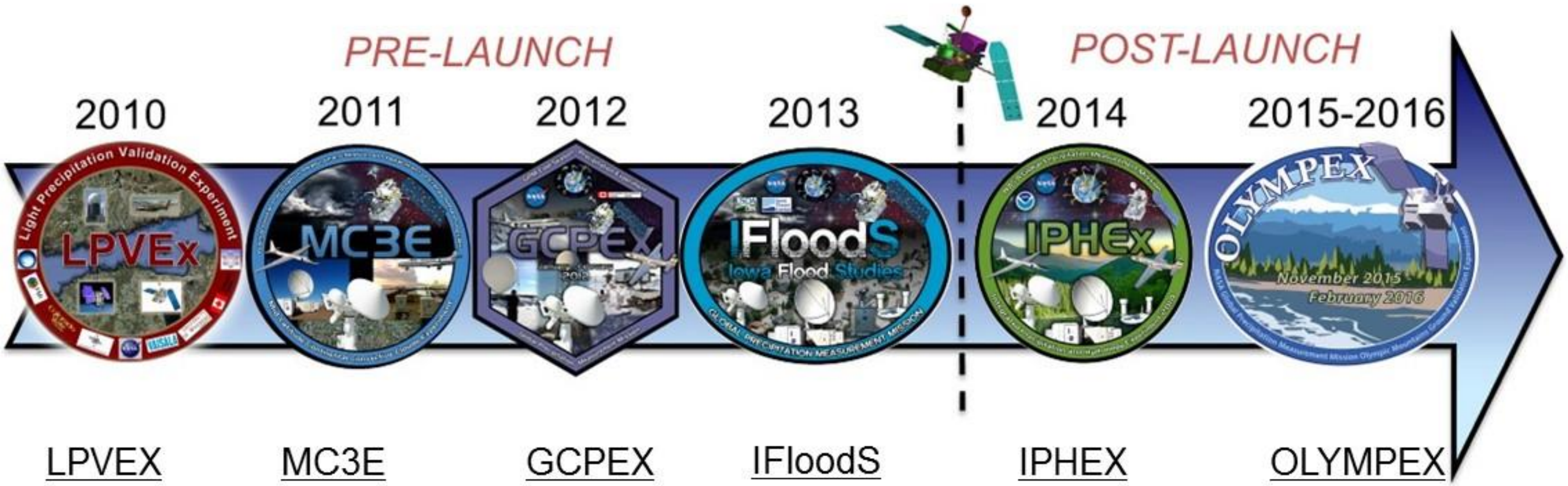




- Datasets and basic approaches developed. Tweak, finalize, finish running analysis over mission to date
- Mission Review
- V5 products?

NASA GPM Ground Validation Field Efforts

GPM GV Lead / Co-Lead



LPVEX	MC3E	GCPEX	IFloodS	IPHEX	OLYMPEX
Finland	Oklahoma	SE Canada	Iowa	North Carolina	Washington
High latitude light rain	Mid-latitude Deep Convection	Mid-Latitude Synoptic and Lake effect Snow	Mid-Latitude Warm season MCS Rain, Hydrology	Mid-Latitude Warm-Season Orographic rain Hydrology	Mid-Latitude Cold Season Orographic, ocean rain, snow Hydrology

GV Contributions to International Partner Campaigns

Environment Canada

C3VP

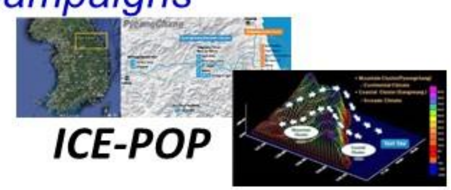
2006/07 Canada Lake effect and synoptic snow

CHUVA PROJECT CPTEC

2010, Brazil, INPE/CPTEC Tropical warm rain

HyMeX

2012 EU- France/Italy, orographic rain



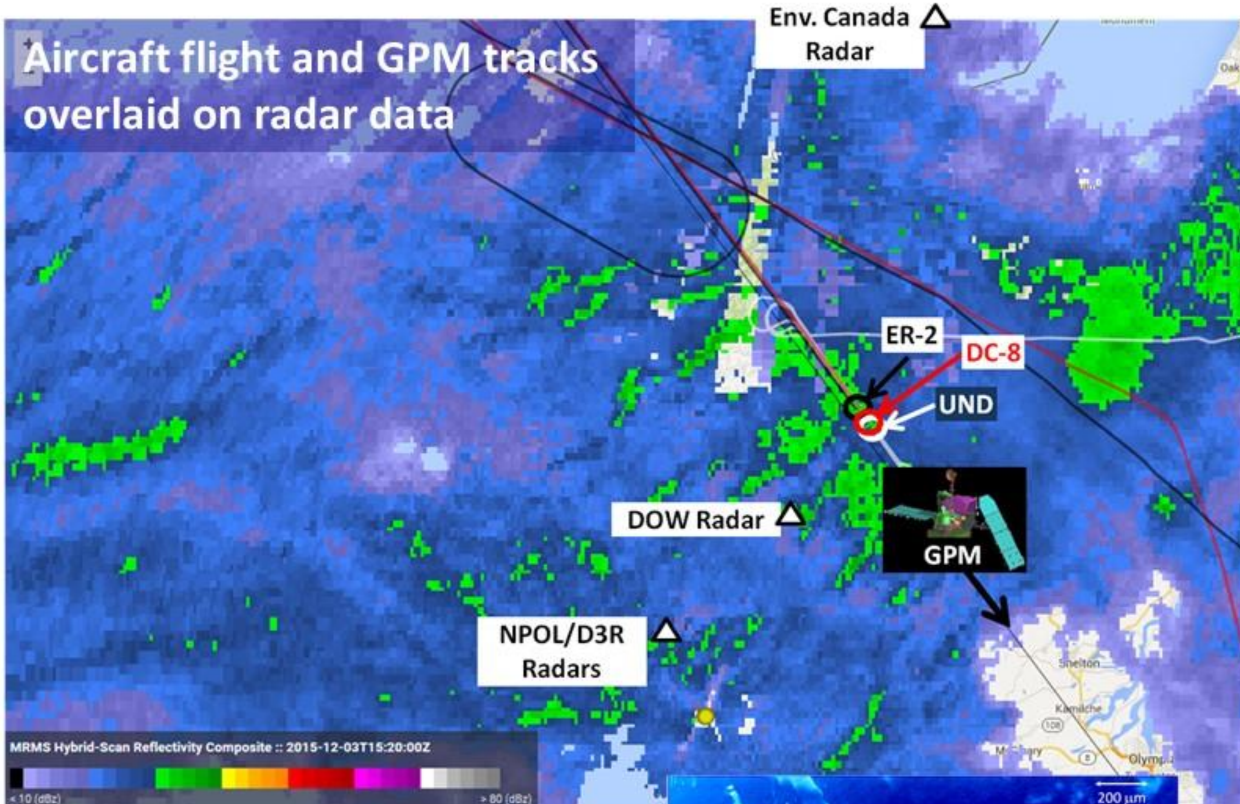
ICE-POP

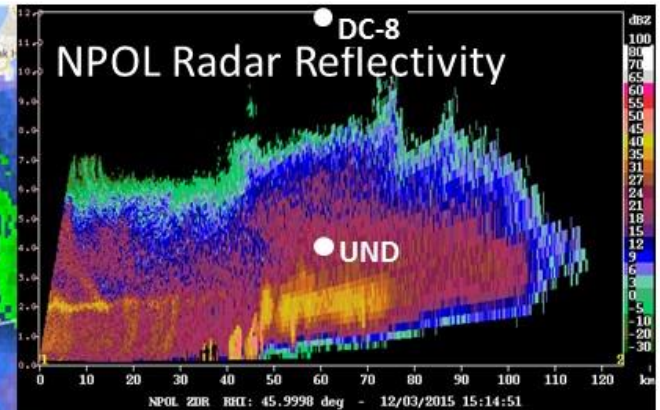
2018, KMA- Korea orographic snow

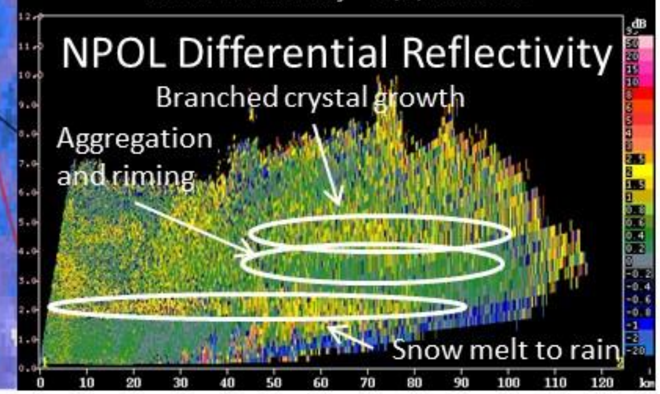
Process and GPM Algorithms

OLYMPEX Conducts first ever 3-aircraft stack (DC-8, ER-2, UND Citation) directly under the GPM Core satellite track within multi-ground-based polarimetric radar coverage

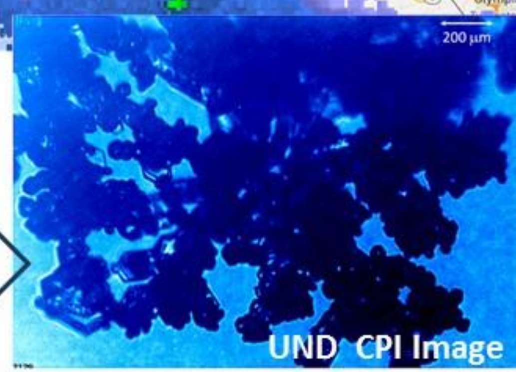
12/3/2015: A complex heavy precipitation event over the Olympic Mountains







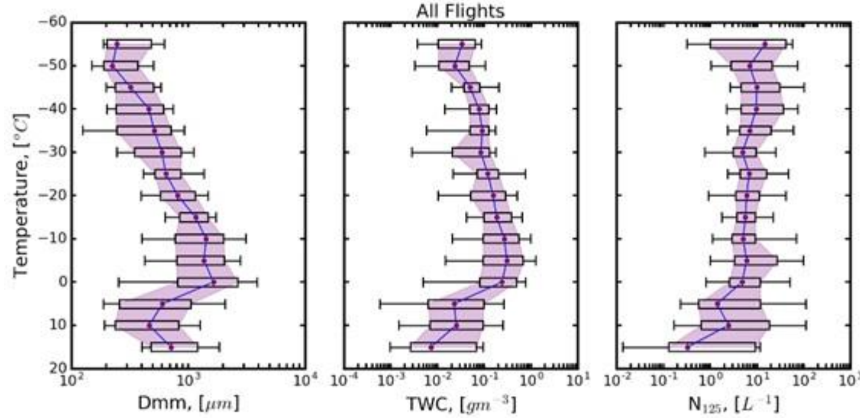
UND Citation cloud particle imager (CPI) observation, 4 km altitude. Indications of rimed (supercooled liquid water), branched and aggregated snow.

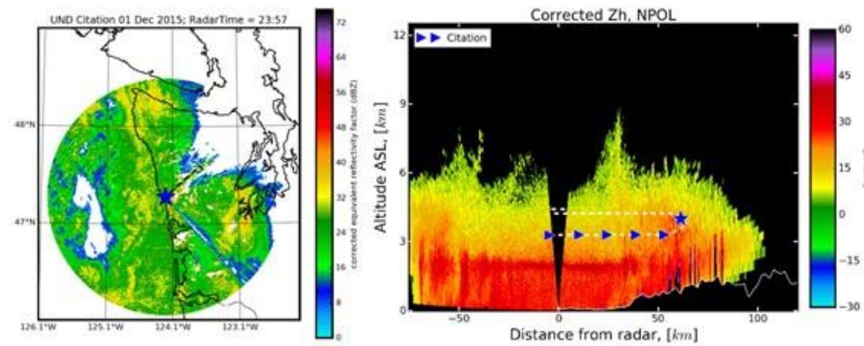


NPOL Radar vertical cross-sections across GPM satellite/aircraft tracks indicating snow crystal growth and aggregation process to make rain below

Building the "column" – PSD working group

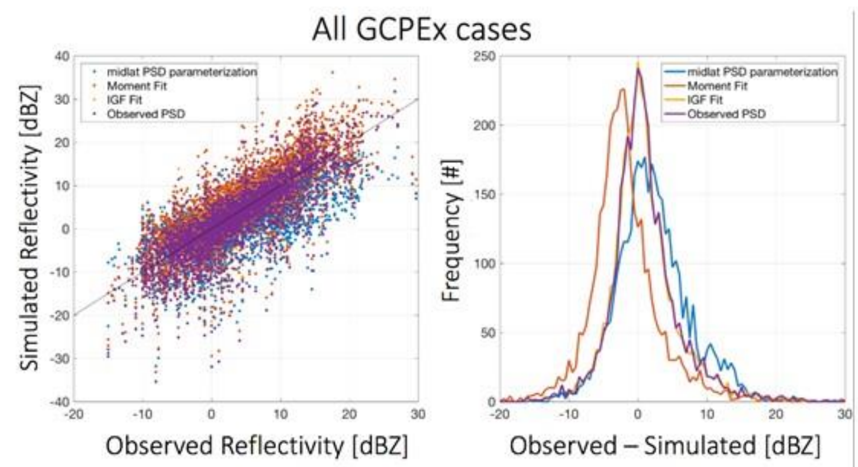
- **GPM retrieval algorithms need accurate assumptions in the vertical**
- GPM needs to move beyond "convective vs. stratiform" thinking - *What are the "regimes" in global precipitation in terms of quantities algorithms need?*
    - Particle habit, size distributions, fall speeds
    - Scattering properties
    - Riming/supercooled water/melting





How can GPM-GV address these unknowns?

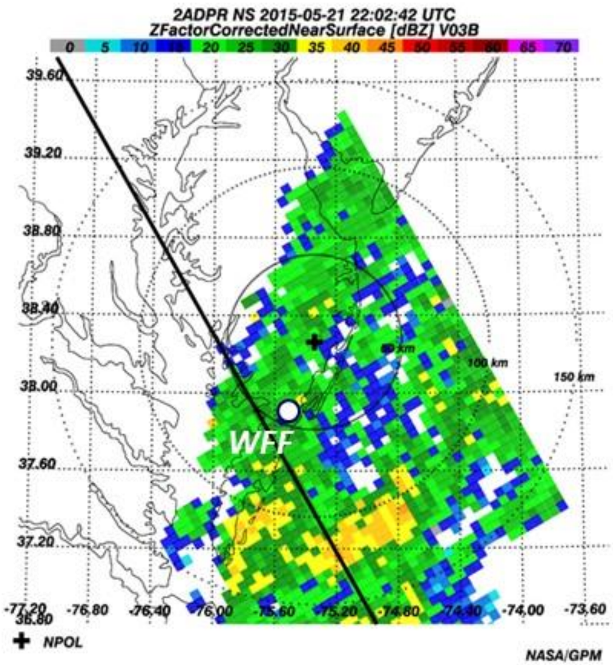
- Statistical analysis of multi-campaign data and long term measurements to determine "regimes" and spatial and environmental correlations
- Process studies of campaign data using combined vertically-resolved and surface in situ measurements, and profiling/scanning radar and radiometer data
- End-to-end error characterization exercises. How do our assumptions impact retrievals?

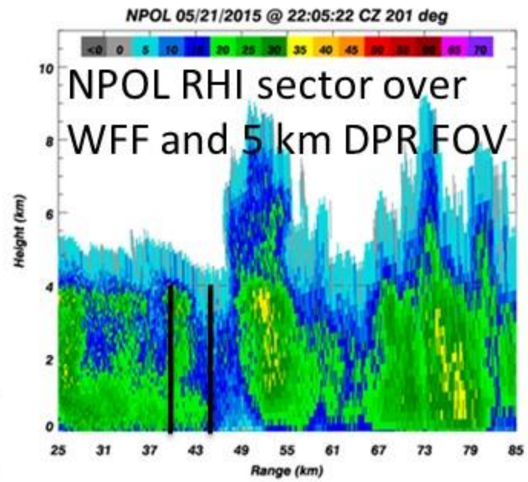


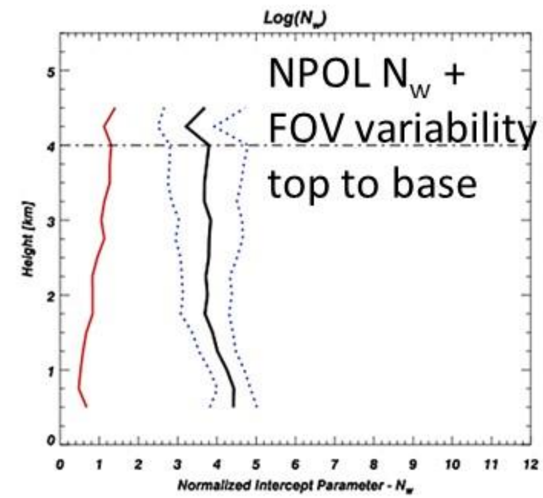
4-D Physics and Algorithm Physical Consistency: Ground-to-Space

Prolific GV data sets exist from field campaigns and Wallops GV Site…….

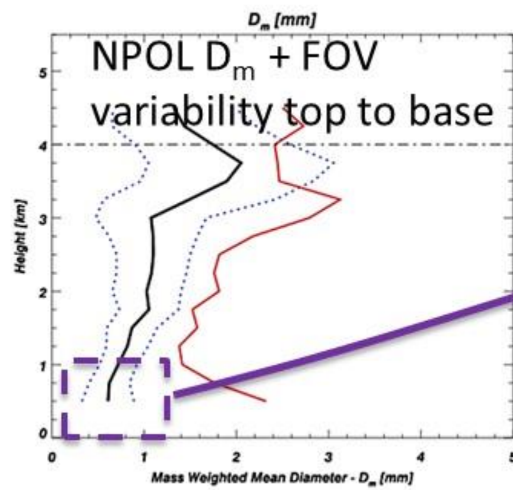
2ADPR NS Over WFF

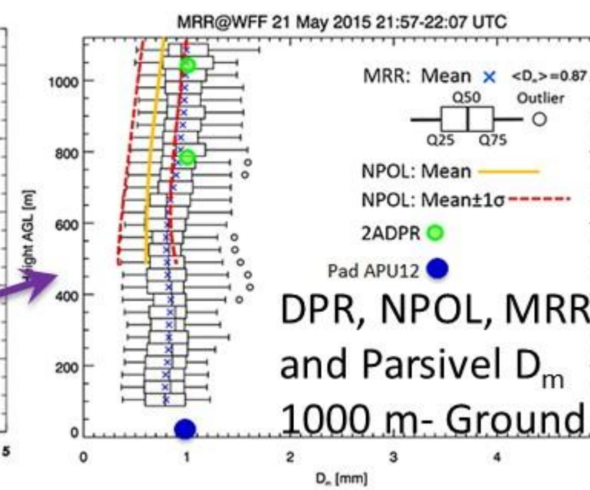






How does intra-FOV variability impact retrievals? Do DPR *and* GV agree, ground-up?

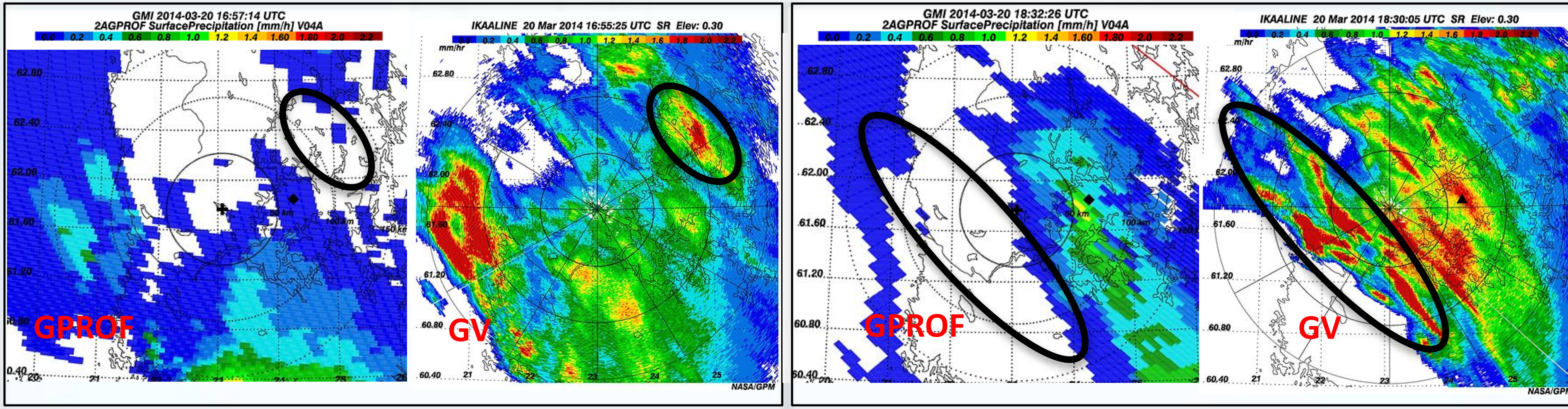


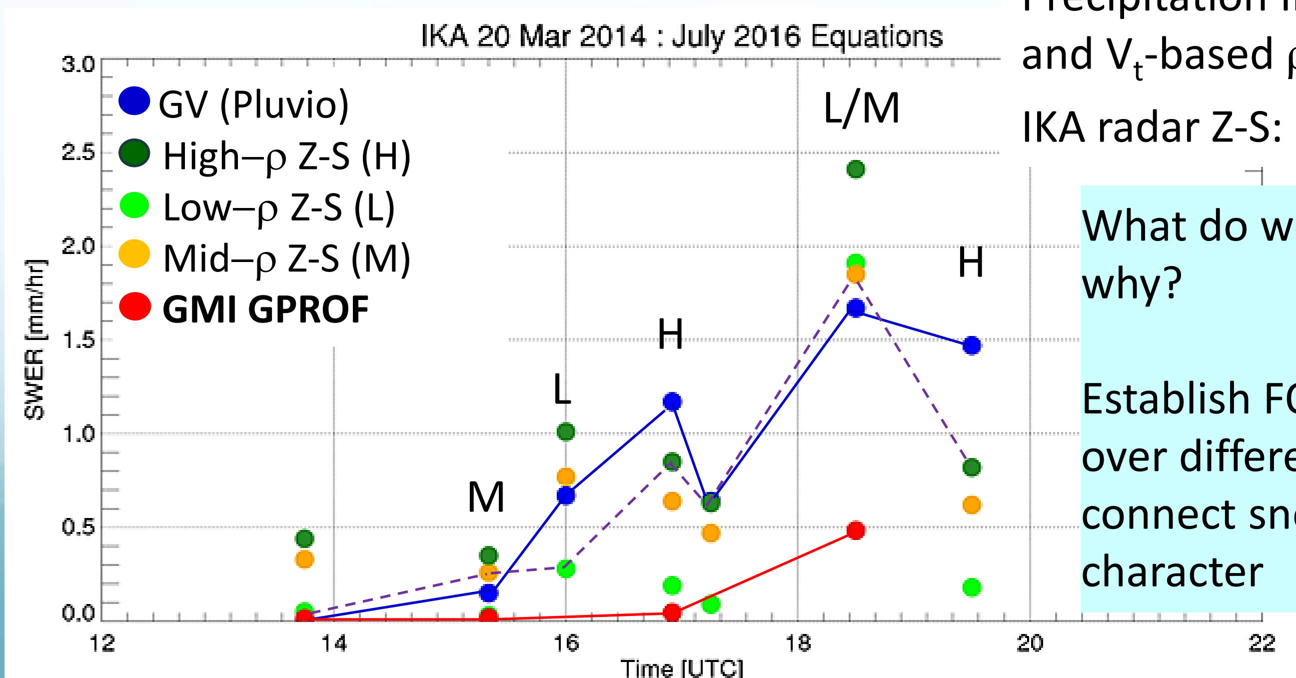


DSD consistency between DPR, NPOL and ground instruments- with observed intra-FOV variability

Snow: Work to Improve Space-Based *and* GV SWER Estimation

Finland, Hyytiala/SNEX Intra-event ρ-Variability w/GPM Overpass





Precipitation Imaging Package (PIP)/Pluvio and V_t-based ρ-D for case-specific Z-S

IKA radar Z-S: 0.3° tilt; 500 m AGL

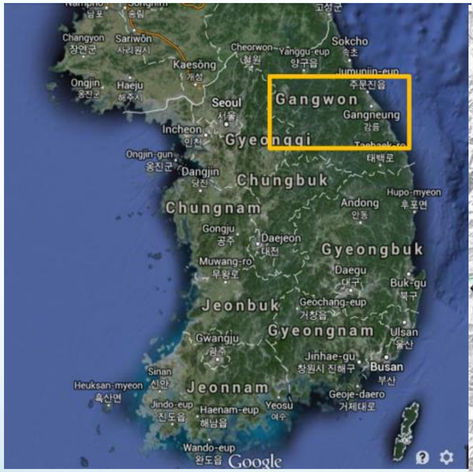
What do we or don't we detect and why?

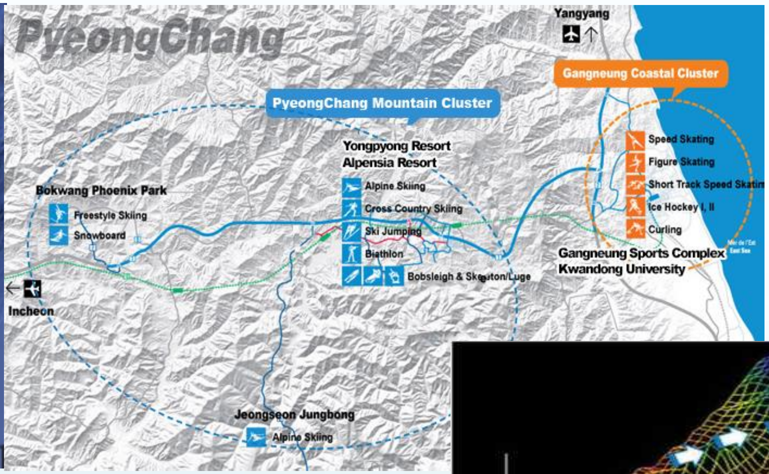
Establish FOV detection thresholds over different land surface types *and* connect snowfall rate to physical character

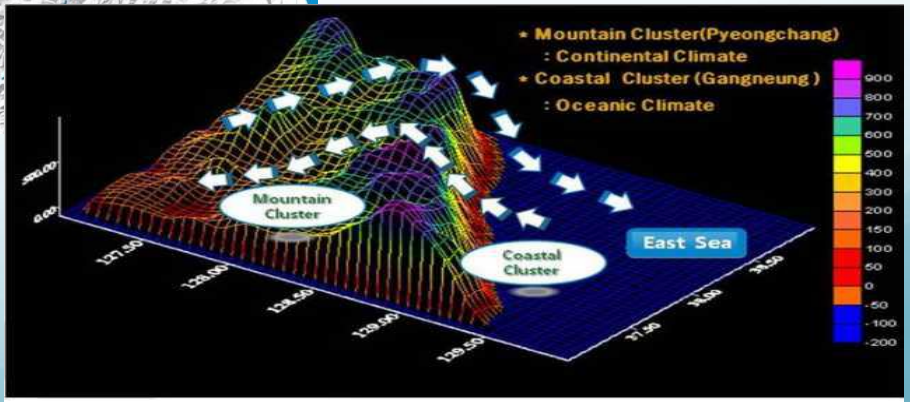
Moiseev, VonLerber, Marks

ICE-POP Snow Experiment 2018
International Collaborative Experiment – PyeongChang Olympics Paralympics

- Winter extreme weather forecast demonstration (research and real-time decision support) and precipitation process research (e.g., measurement and prediction of orographic/terrain forced snow)
- KMA Lead, international investigator team
- GPM GV: D3R Radar, PIP, Pluvio, Parsivel deployments; GSFC/MSFC NUWRF Effort
- Work up: 2016-17; 2018 Intensive Observation Period (IOP) with 2018 Winter Olympics
- Coastal (Gangneung) and PyeongChang Mountain clusters: High res. international forecast models, dense surface observations (dual-pol/multi-freq. radars, gauges etc.), NIMR microphysics aircraft

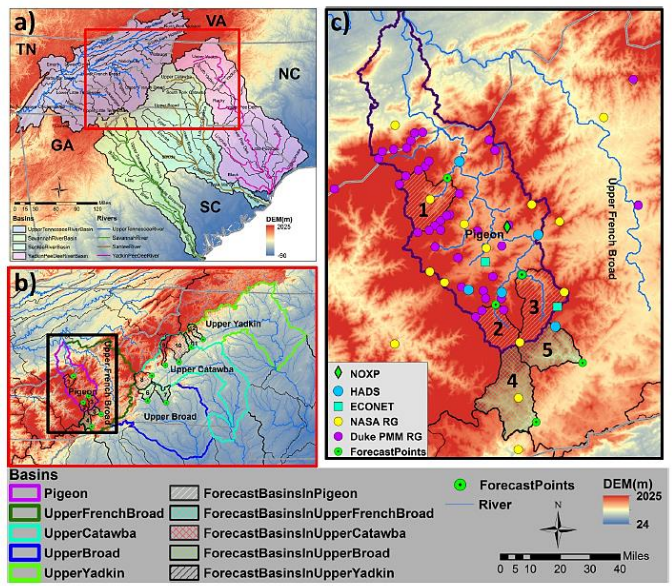




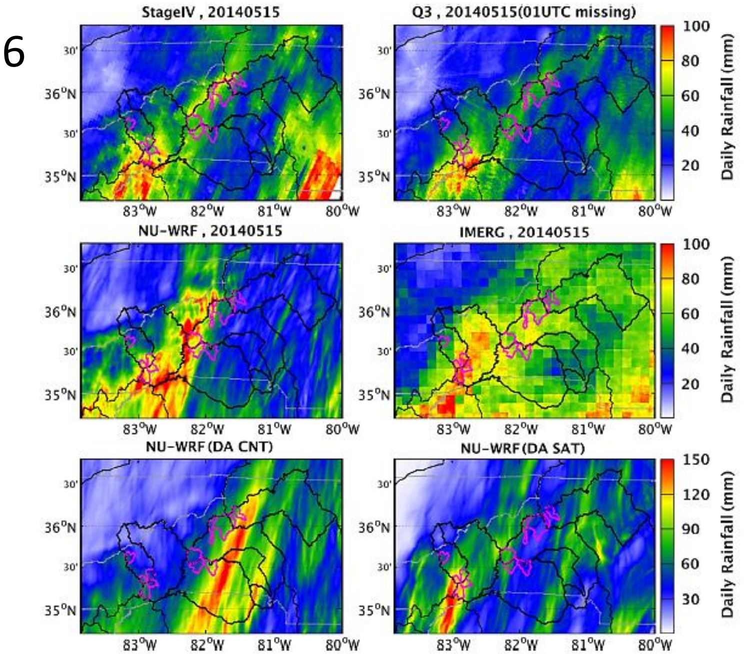


"Modes" of snow: Heavy orographic via mix of migrating westerly cyclones or easterly "backdoor" cold fronts (anticyclones) with key adjacent ocean moisture fluxes, terrain gradients.

Continued and Extended Integrated Hydrologic Validation…..E.g., IPHEx



J. Tao et al., 2016
J. Hydrology



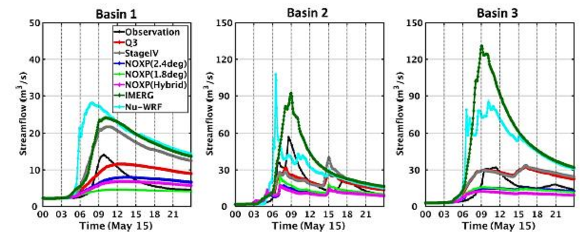


Fig. 8. Forecast/hindcast results on May 15, 2014 using multiple QPEs (Q3, StageIV, NOXP data at 1.8° and 2.4° elevation angles and the hybrid data, and IMERG) and QPF from Nu-WRF in headwater catchments in the Pigeon River Basin (Basin 1–3, from left to right).

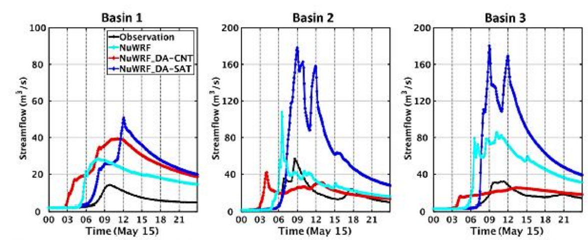


Fig. 9. Forecast results on May 15, 2014 using the improved NU-WRF QPFs by assimilating conventional ground-based observations (DA-CNT), and assimilating satellite-based data (DA-SAT) (GPM GMI and SSMIS precipitation-affected radiance) also for the three headwater catchments in the Pigeon River Basin (Basin 1–3, from left to right).

- Improved QPE using IPHEx field data with Q3;
- Improved NUWRF forecast of storm location/timing with GMI and SSMI/S satellite radiance assimilation
- Improved streamflow forecasting- with large improvement enabled by additional assimilation of stream flow in the DHCM
- Result sensitive to basin scale

Tie in more physics and use approach for IFloodS, OLYMPEx or other similar data?

Applications extension/expansion!

Thanks!

GPM Core L1 Validation Work

Footprint and Area Selection

- 5 km DPR / 15 km GMI footprint "effective" resolution assumed
- 50 km x 50 km averages (of footprints), but also computing footprint bias and scaled random error (5 km/15 km footprints to 50 km scale; Steiner et al., 2003) to mitigate small sample numbers of 10 mm h^{-1} rain rates experience over in 50 km grid boxes.

Instantaneous rain rates for "reference"

- MRMS Gauge-bias-adjusted radar subset over CONUS and central/southern U.S.
- Radar Quality Index = 1; NUBF > 80% FOV fill, 25% of 50 km box filled with > 0 mm/hr
- KwajPol/other sea-based radars (e.g., Middleton Island, AK) triplet of dual-pol estimators
- GPROF (GMI) Thresholds: currently use POP > 40% to ensure > 0 rain rates
- $5^{th}/95^{th}$ percentile outliers removed

DSD- Drop Size Distribution (D_m)

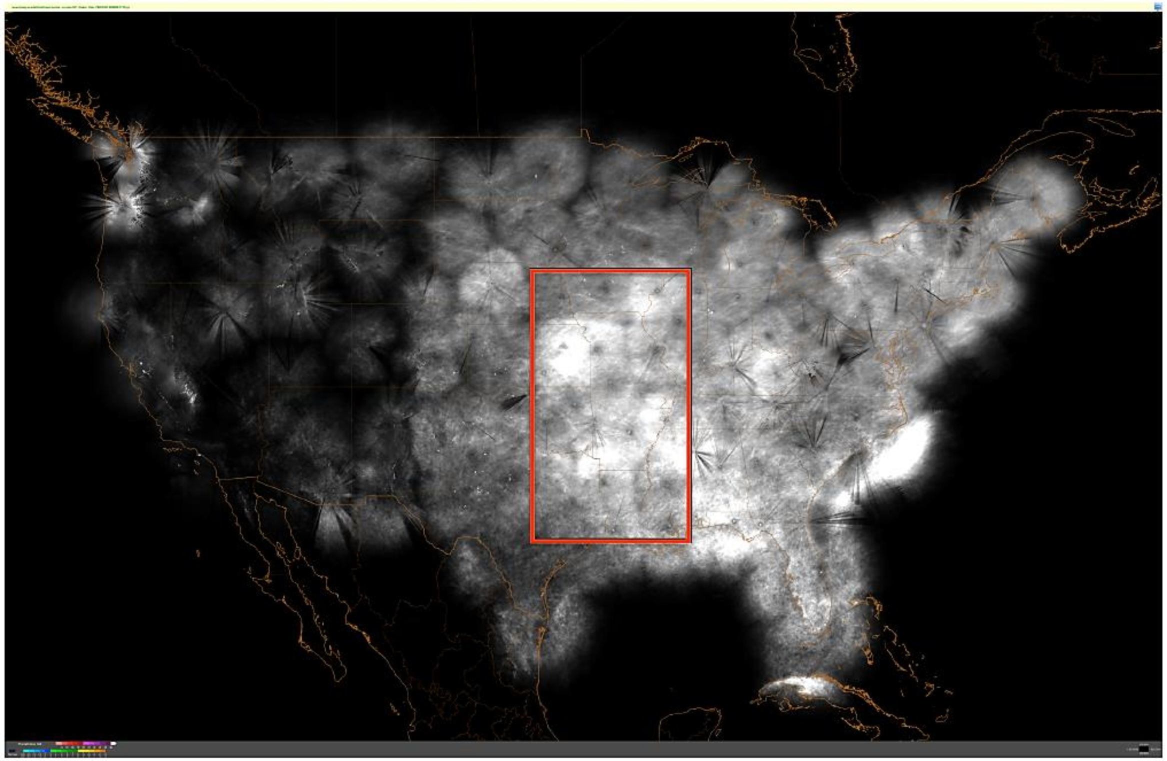
- GV Disdrometer-based polarimetric radar retrievals of D_m- scaled up to Validation Network ~60-radar subset of U.S. WSR-88 dual-pol network.
- Multiple regimes (field campaigns and long term sites); data subset used in error testing

Snow (Detection)

- MRMS constraint of height off surface- Datatype 3.0 (< 1.5 km); precip type id= snow.
- GMI POP 40%, <50% Liquid precip fraction (also Combined Alg.); DPR "phase near surface"
- Snow index and METAR or like database

Defining an MRMS "reference" area for L1

MRMS best observation areas

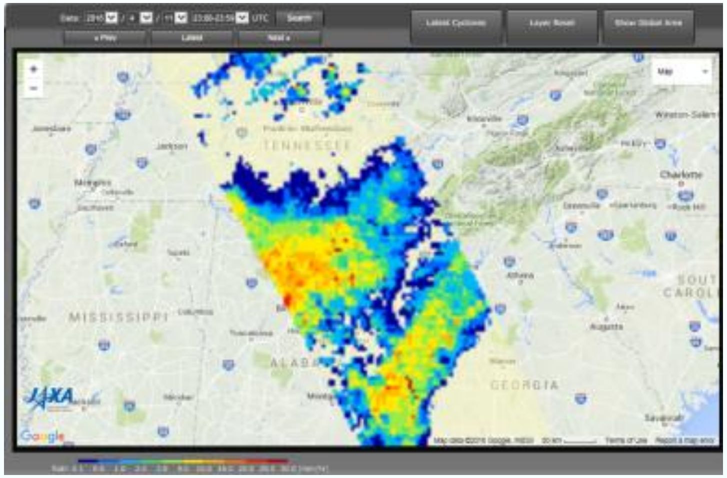


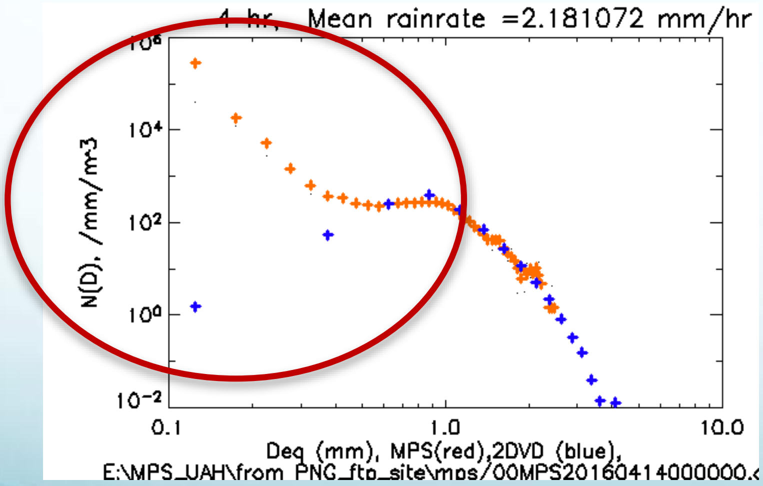
Gamma assumptions?

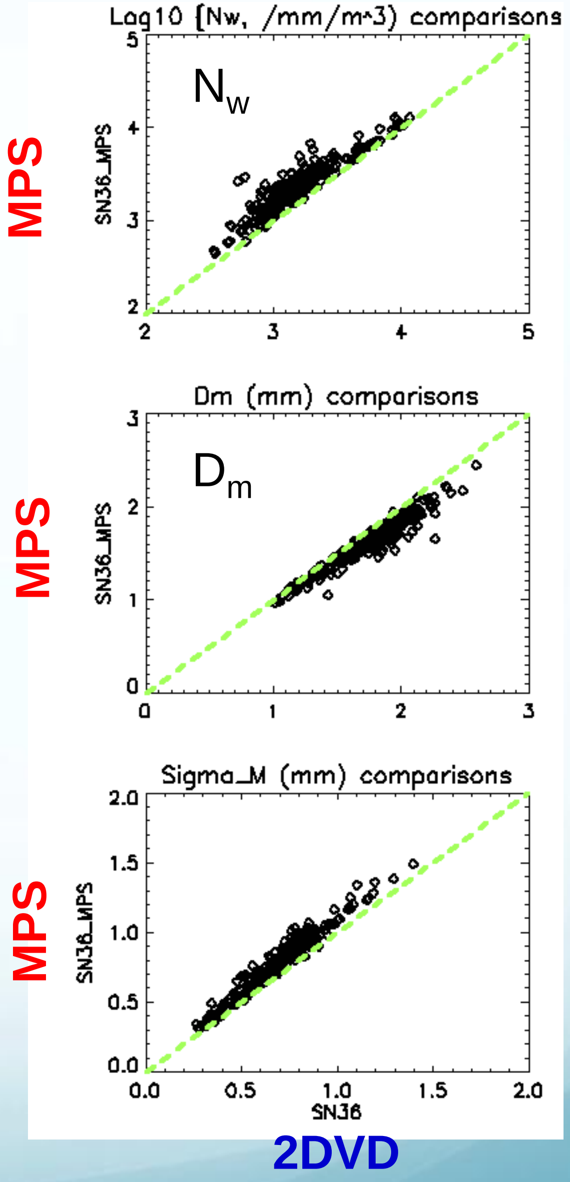
GV-measured rain DSD limitations……small drop impact?

DMT MPS vs. 2DVD Disdrometer

April 11 2016







M. Thurai, P. Gatlin

Ocean: Kwajalein(KWAJ) and Middleton Island AK (PAIH)

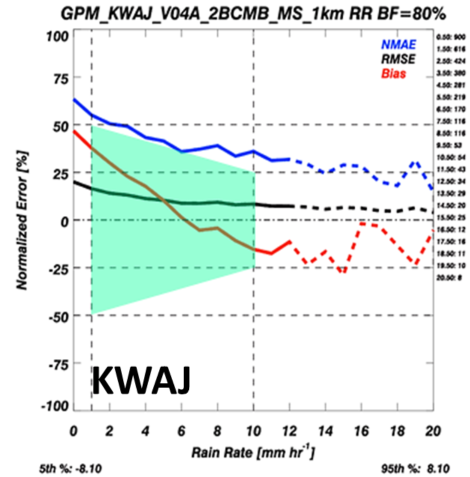
March 2014 – June 2016

Footprint stats with RMSE scaled to 50 km

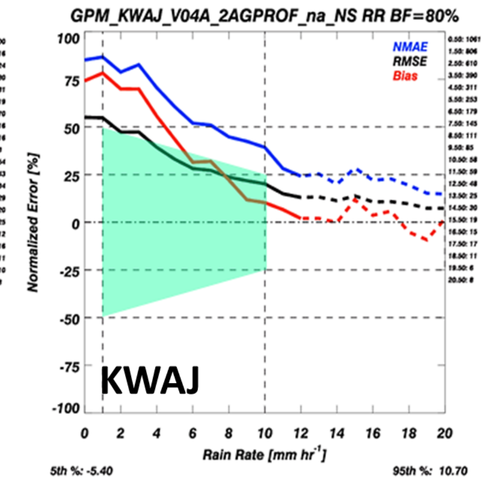
Hard to get heavier rates in sufficient numbers at PAIH, but within L1 requirements otherwise

*DPR and KuPR both within L1 requirements at both locations

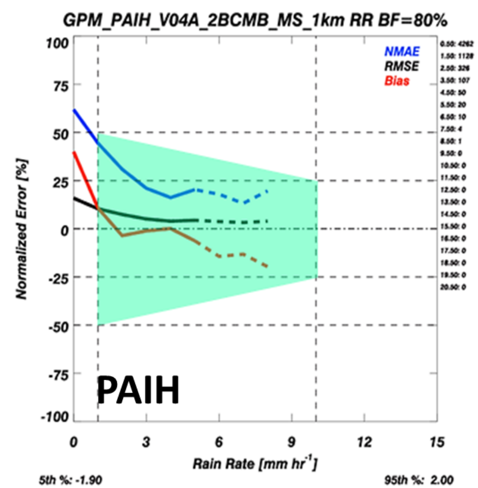
2BCMB MS



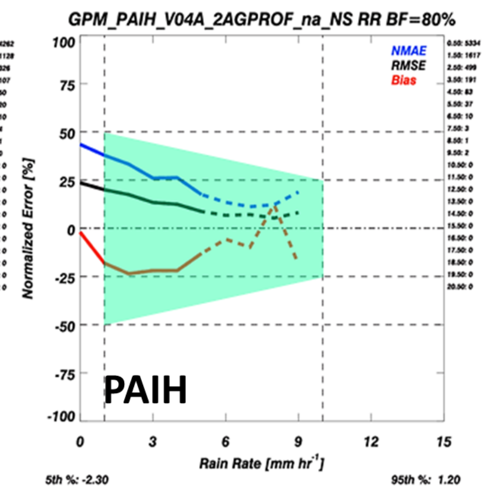
2AGPROF



2BCMB MS



2AGPROF



BIAS　　FOV MAE　　50x50 Scaled RMSE