NASA Cal/Val and Algorithm Virtual Workshop

24-25 March 2020

Virtual Workshop Objectives

- Help *identify priority research topics* that will help advance GPM precipitation products over the next few years.
- Develop *action plans* to coordinate Ground Validation (GV) activities to help Satellite Algorithm (SA) scientists meet their testing and validation requirements.

Workshop Format

- Four 2-hour sessions held over two days
- Sessions held at different times to enable European and Japanese colleague participation
- Over 12 different possible research topics were identified during workshop
- Online participant polls enabled a collaborative and consensus process
- Identified *three priority research topics* and one GV training opportunity

Organizers

NASA GPM Particle Size Distribution (PSD) Working Group co-Chairs:

Christopher R. Williams	University of Colorado Boulder
Stephen Nesbitt	University of Illinois, Urbana-Champaign
Claire Pettersen	University of Wisconsin – Madison

Steering Committee

Chanda V. Chandrasekar	Colorado State University
Patrick Gatlin	NASA Marshall Space Flight Center
Pierre Kirstetter	University of Oklahoma
Guosheng Liu	Florida State University
Sarah Ringerud	NASA Goddard Space Flight Center

Executive Committee

S. Joe Munchak	GPM Deputy Scientist for GV
David Wolff	GPM GV System Manager

Workshop Outcomes – Formed Research Topic sub-Groups

Lead	Research Topic
Steve Durden & Mircea Grecu	Blind Zone
Patrick Gatlin	DSD Parameter
Pierre Kirstetter	Phase Discrimination
Patrick Gatlin & Pierre Kirstetter	Validation Network Training

Each Research Activity sub-Group has **GV** and **SA** scientists

Blind Zone Research Activity

Leads: Steve Durden and Mircea Grecu

Definition: "Blind zone" is the region where real radars miss the echoes that an ideal radar would observe.

General Causes: Noise and clutter that are stronger than the signal

Examples:

- Precipitation reflectivity below the expected minimum detectable reflectivity
- Signals in some rays or bins obscured by surface return in antenna sidelobes
- Shallow precipitation obscured by mainbeam surface return
- Orographic precipitation where surface clutter is worsened by topography

Purpose of the Blind Zone Group

- Survey work that has been done or is currently being done
- Facilitate communications between blind zone researchers (set up a Slack Channel)
- Identify areas that need further work

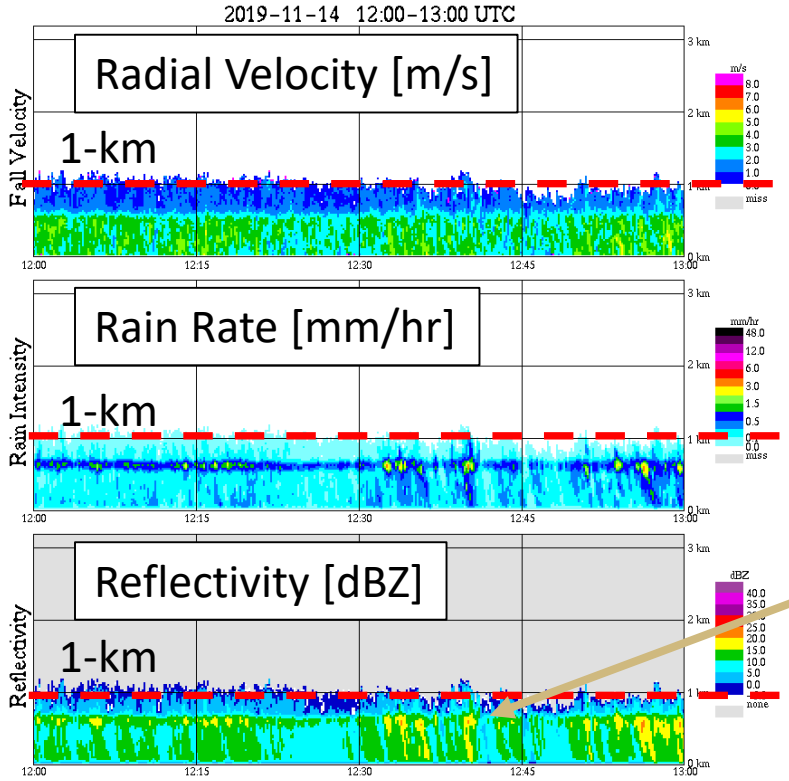
Examples of Current Work Understanding Blind Zone Effects:

Shallow precipitation

Current work:

i) Use of MRR data sets to evaluate shallow and/or light precipitation

ii) Evaluate surface radar vs DPR-derived databases



(contributed by Chris Kidd)

Ground-based MRR-Pro at Plymouth Marine Laboratory (UK)
(Courtesy Tim Smyth, PML)

<u>Note Brightband below 1 km.</u>
Even if DPR could see this precipitation, it would also need to perform phase identification.

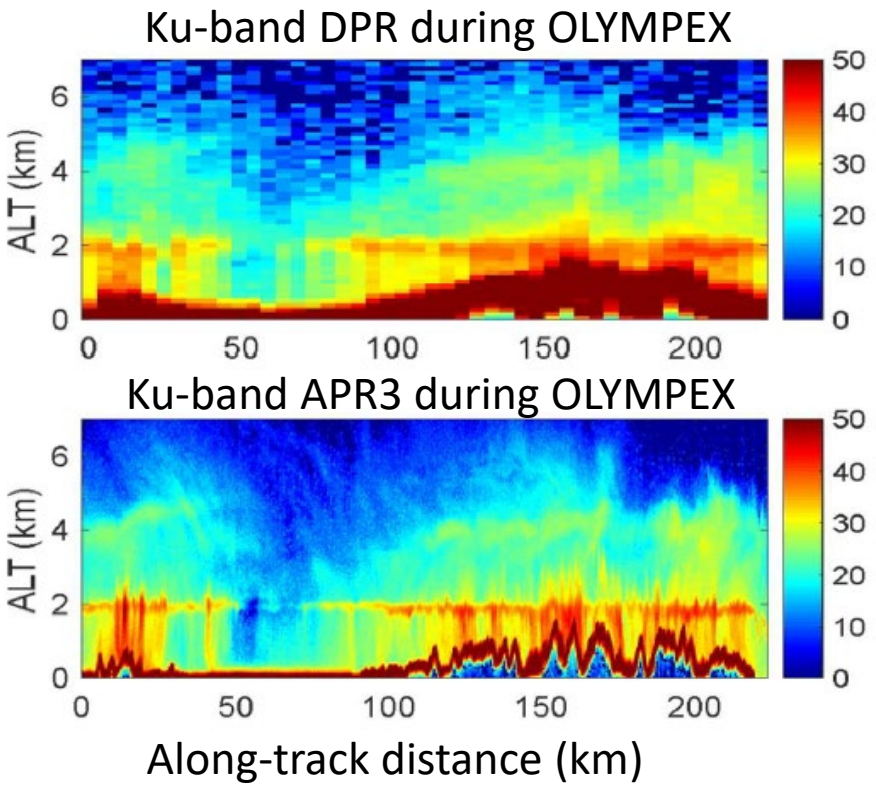
Orographic Precipitation

Current work:

i) Use the APR3 observations within the DPR clutter to understand precipitation structure

ii) Use Machine Learning techniques to predict features not resolved

(Contributed by Durden et al. 2020: IEEE GRSL)



Diagramming Blind Zone Conditions and Possible Solution Methods

Blind Zone Condition
Missing measurements over some set of DPR ranges

Issue

- Missing data due to **clutter**
- Missing data due to **low signal-to-noise**

Cause

- Over Ocean: antenna pattern and pulse shape clutter
- Over Land: Same as ocean but enhanced by orography
- Loss of near-surface signal due to heavy attenuation
- Loss of signal due to light rain below minimum dBZ

Solution

Methods:
a. Estimate DPR antenna clutter and subtract
b. Estimate surface pulse shape and subtract (as done for CloudSat)
c. Fill in missing data as for land

Methods:
a. Extrapolate using signal in unaffected bins
b. Estimate missing data from other information (e.g., rain type, VPR stats)

Methods:
a. If loss only at Ka-band, revert to Ku-band only retrieval
b. Use VPR stats as for clutter due to orography

Methods:
a. Radiometer-only

Other methods?

DSD Parameterization Research Activity

Lead: Patrick Gatlin

Main Activities:

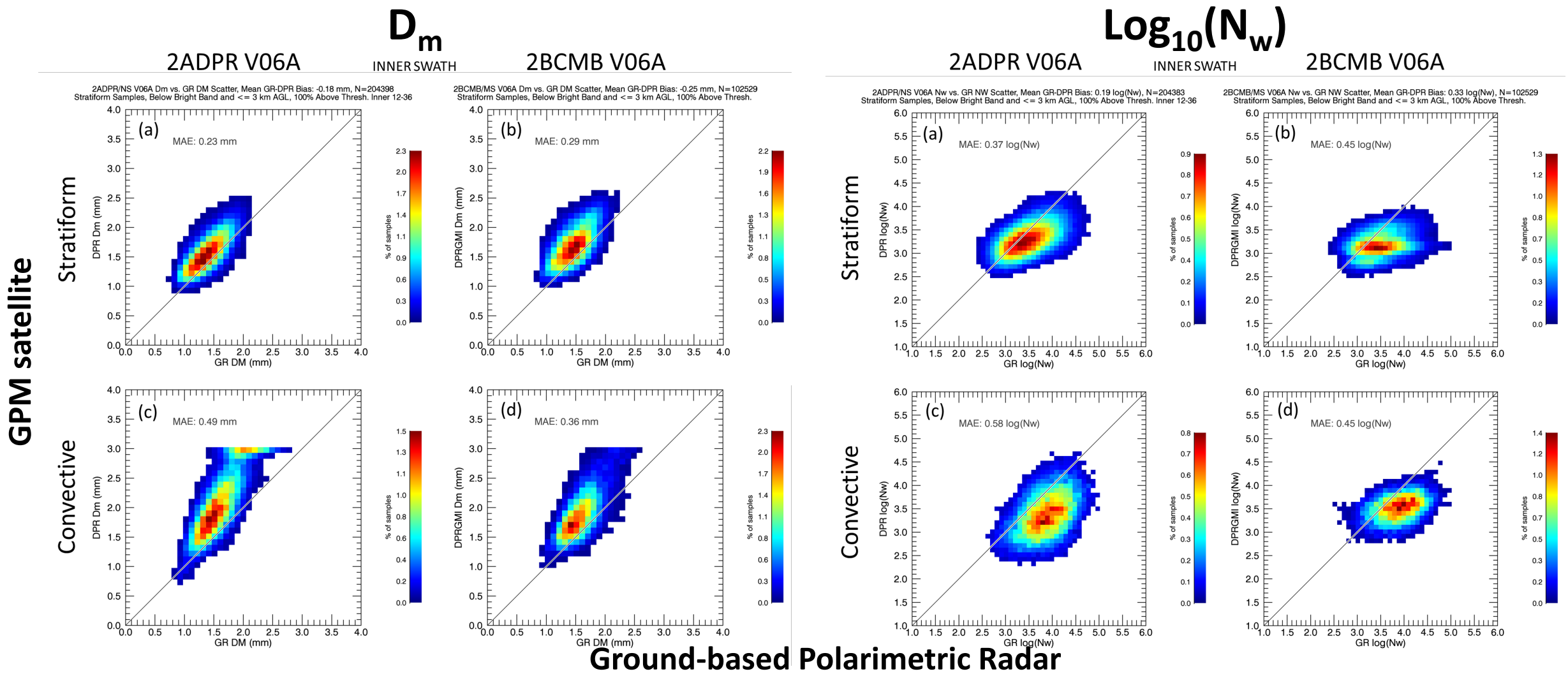
Activity #1: Test and refine the R-Dm relationship used in 2ADPRv6

Activity #2: Use 2ADPR vertical profile information to refine DSD retrievals

Activity #3: Retrieval of snow PSD

Activity #4: Possible N_w constraints in Combined Algorithm based on disdrometer N_w-D_m relationships

Motivation for the DSD Parameter Research Activity: How well are GPM algorithms estimating the DSD?



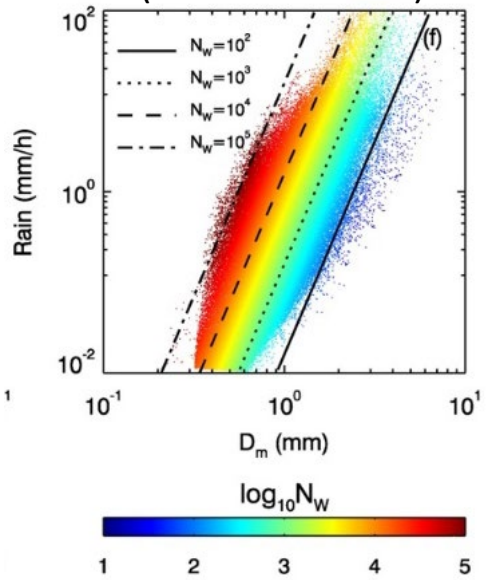
Gatlin, P.N.; Petersen, W.A.; Pippitt, J.L.; Berendes, T.A.; Wolff, D.B.; Tokay, A.: The GPM Validation Network and Evaluation of Satellite-Based Retrievals of the Rain Drop Size Distribution. Atmosphere (Basel). ***2020****, 11, 1010.*

Activity #1: R-D_m relationship

A. Liao, L.; Meneghini, R.; Iguchi, T.; Tokay, A. Characteristics of DSD Bulk Parameters: Implication for Radar Rain Retrieval. *Atmosphere* **2020**, *11*, 670.

- Analyzed >200K DSD spectra from GPM field campaigns
- Variation in R-D_m is a result of variation in N_w
- R-D_m relations used in 2ADPR pretty good except at larger D_m
- A constant N_w may be an alternate constraint for R-D_m
- Retrievals of R, D_m or N_w in region where DFR < 0 is ambiguous
- Less uncertainty in gamma model estimates of R than of D_m and N_w

(Liao et al. 2020)

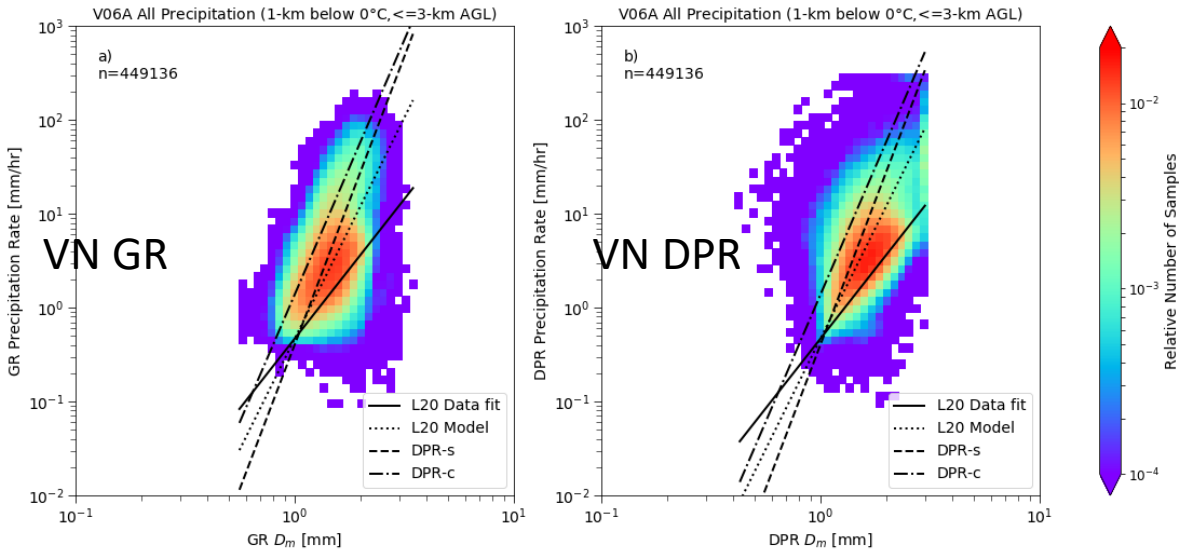


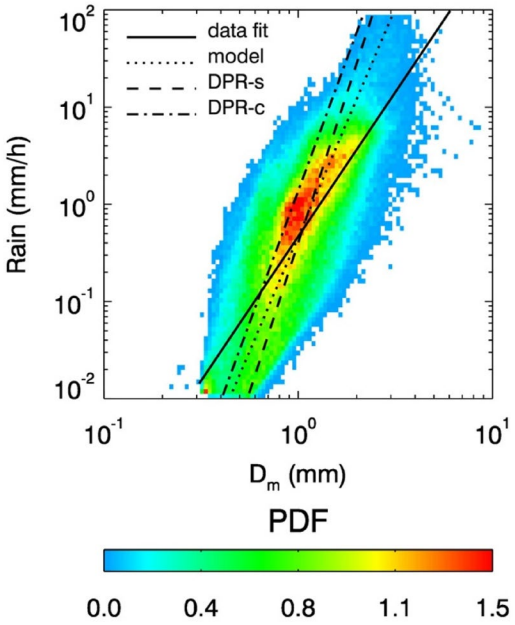
B. Validation Network

- R-D_m being adjusted too much?

C. Argentina DSDs from RELAMPAGO suggests terrain influence (Paola Salio)

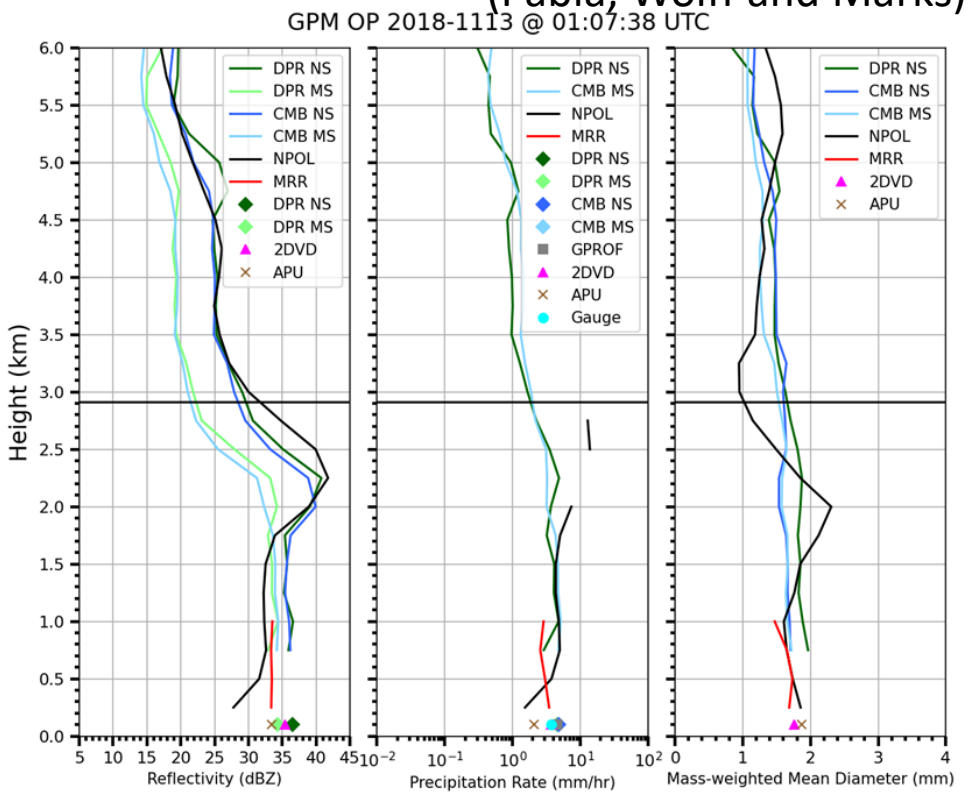
D. Western Ghats DSDs and R-D_m (Chuntao Liu)





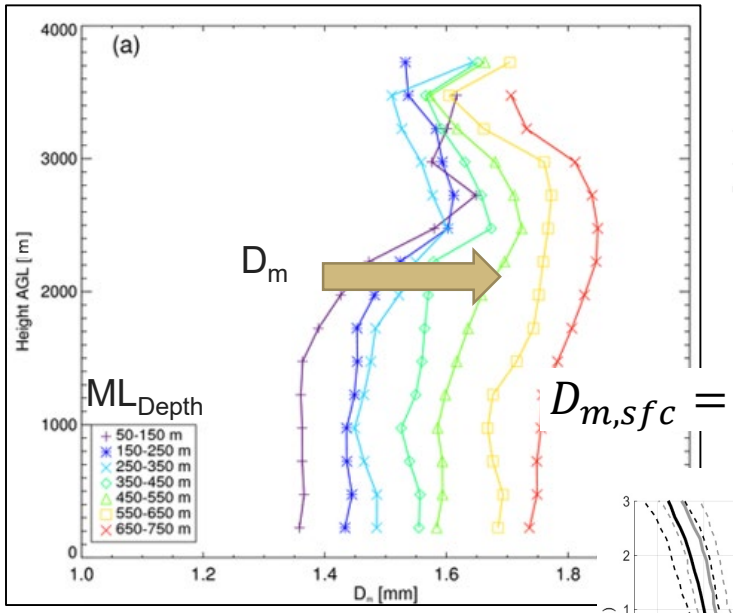
Activity #2: Vertical profile from 2ADPR to refine DSD retrievals

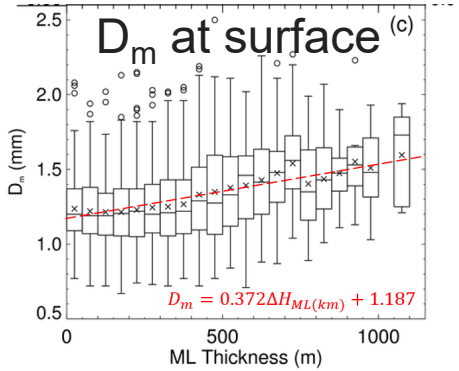
Use WFF instruments to examine low-altitude variability (Pabla, Wolff and Marks)



Some overlap here with "blind zone" subgroup activities

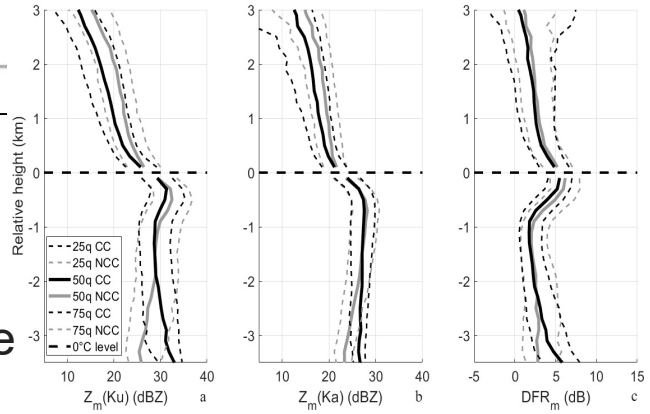
Use Melting Layer (ML) characteristics and warm rain model to prescribe D_m variability





$$D_{m,sfc} = 0.372 * ML_{Depth} + 1.187$$

D_m increases with depth of ML (Gatlin et al. 2018)



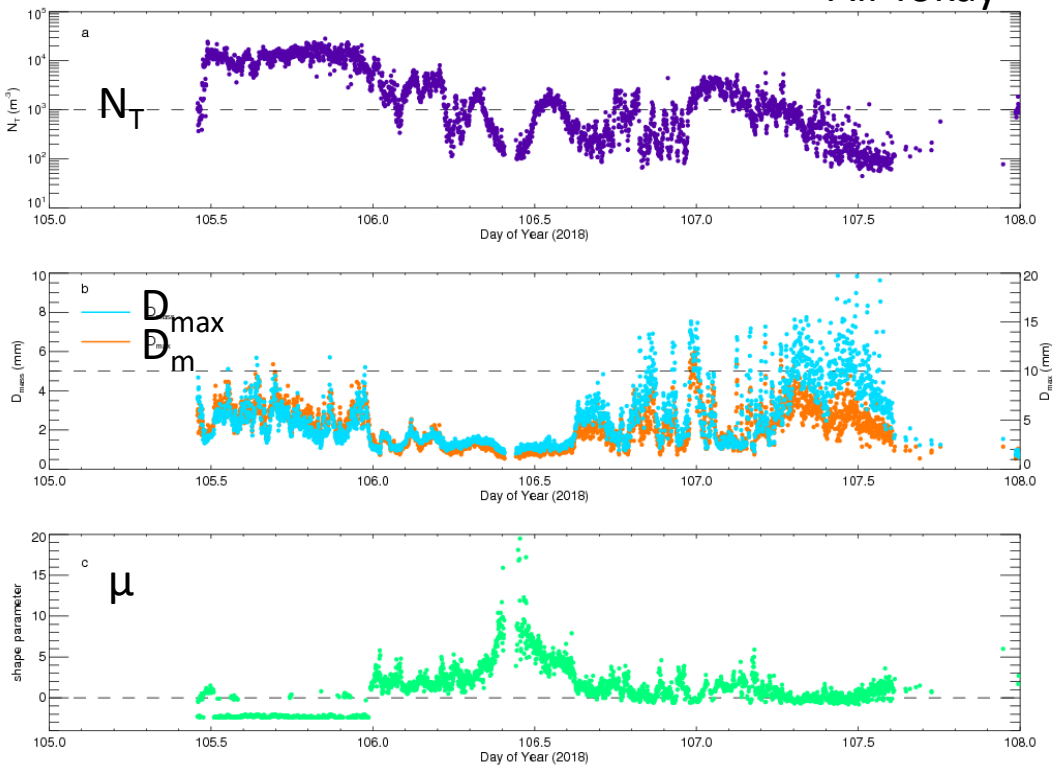
Collision-Coalesence near surface (Porcacchia et al. 2019)

Activity #3: Retrieval of snow PSD

A. R-D_m not optimal for snow (Chase et al. 2020, Atmosphere - Special Issue)
   - Neural network approach is promising (Chase et al. 2020, in review)

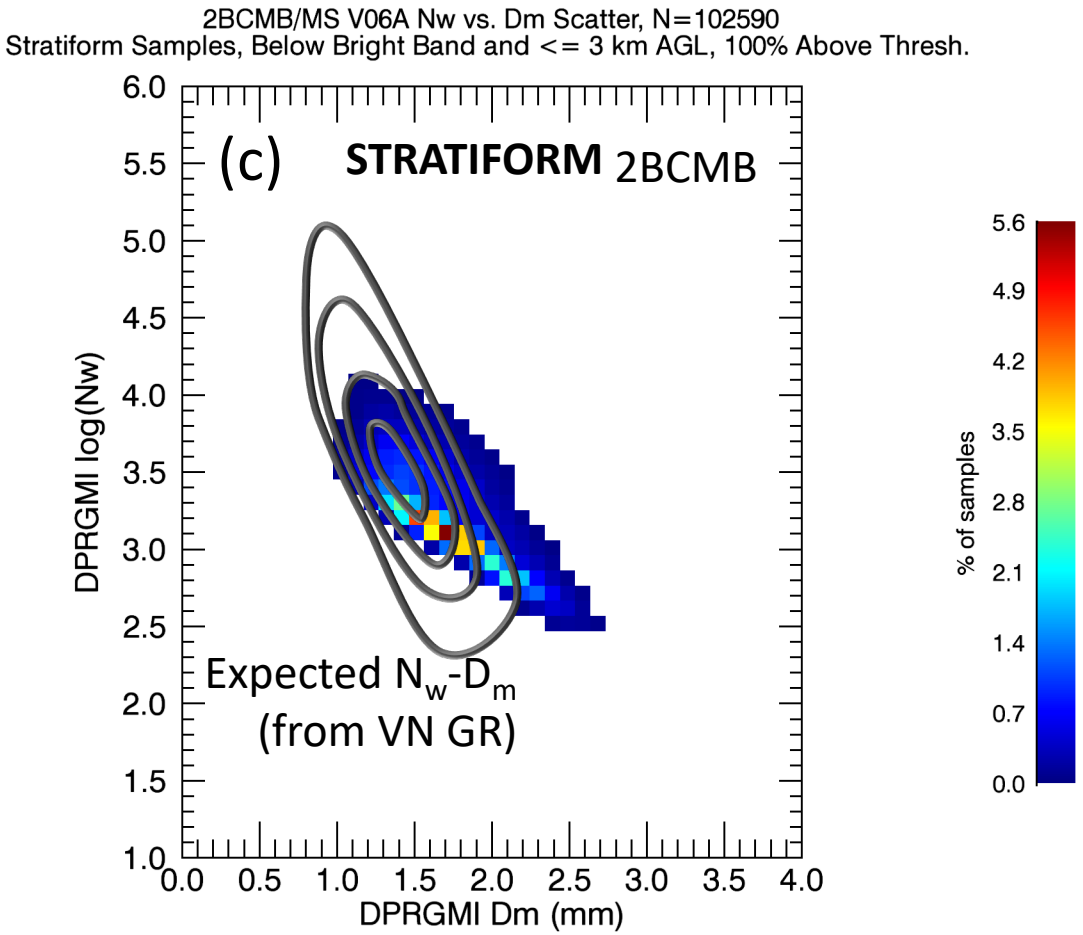
B. Ground-based studies to constrain snow PSD retrievals:
   - Variability in PSD and bulk quantities with different snow-liquid water ratio events (Pettersen et al. 2020 MQT PIP study and Yu et al. 2020 S. Korea APU/PIP study)
   - Analysis of MQT dataset by Tokay reveals (in terms of unmelted particle):
     - Dynamic range of D_m and D_{max} are wider in snow than in rain
     - High concentration of small flakes results in high N_T and concave up shape ($\mu < 0$) of the size spectra

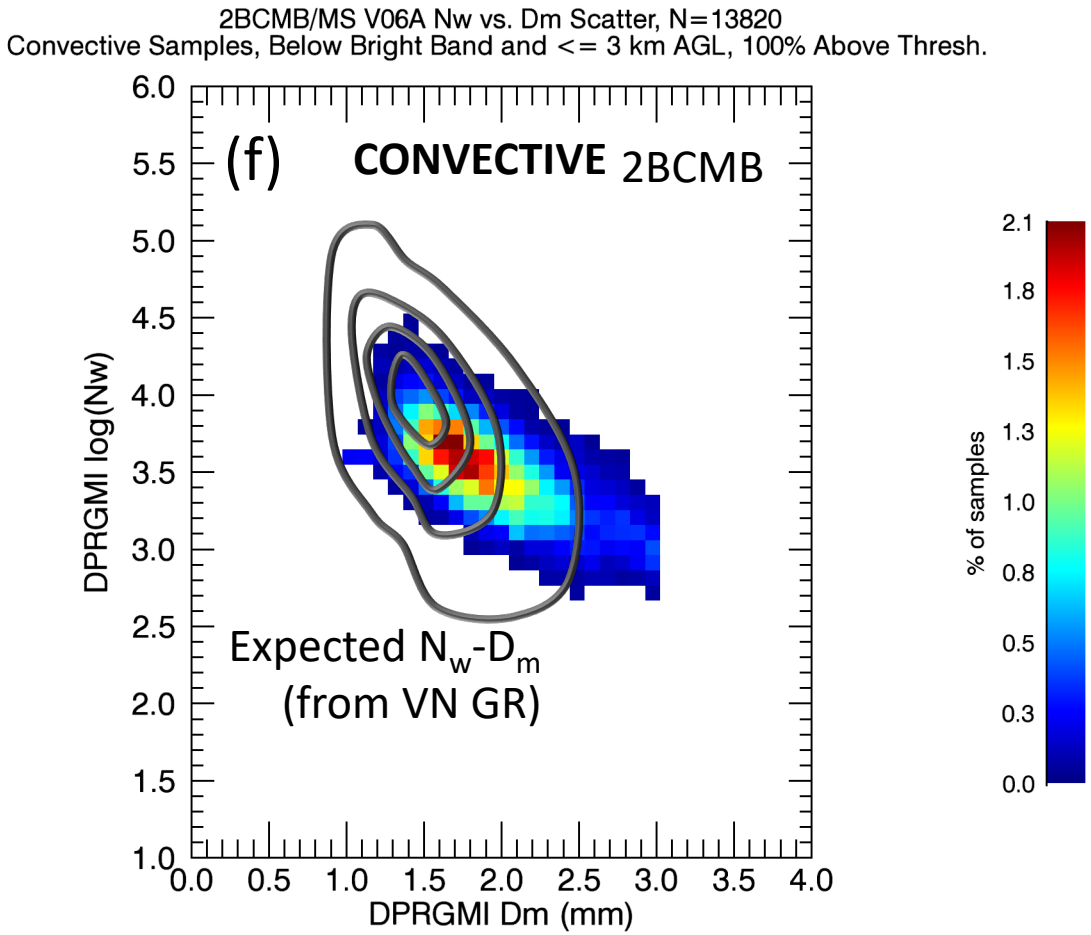
Ali Tokay



Activity #4: N_w Constraints in the Combined Algorithm

- Analysis of disdrometer data suggests an Nw-Dm constraint
  (e.g., Gatlin et al. 2020; Dolan et al. 2018)
- Combined Algorithm exploring N_w constraint in V7 based on disdrometer results
  (Bill Olsen discussed on Thursday)





Research Paper Deliverables

Special Issue in journal *Atmosphere*:

"Measurement and Modeling of the Precipitation Particle Size Distribution"

https://www.mdpi.com/journal/atmosphere/special_issues/Precipitation_Particle

Editors:

- Patrick Gatlin (Lead) – NASA Marshall Space Flight Center
- Merhala Thurai – Colorado State University
- Christopher Williams – University of Colorado Boulder
- Elisa Adirosi – Institute of Atmospheric Sciences and Climate, Italy

Special Issue contains ten (10) articles relevant to our PSD WG efforts

- GPM retrieval
- Snow
- Orographic
- Disdrometers
- Includes papers from several WG members

Phase Discrimination Research Activity

Leads: Pierre Kirstetter

Discuss @ November PSD WG telecon:
19 November, 11 am Eastern

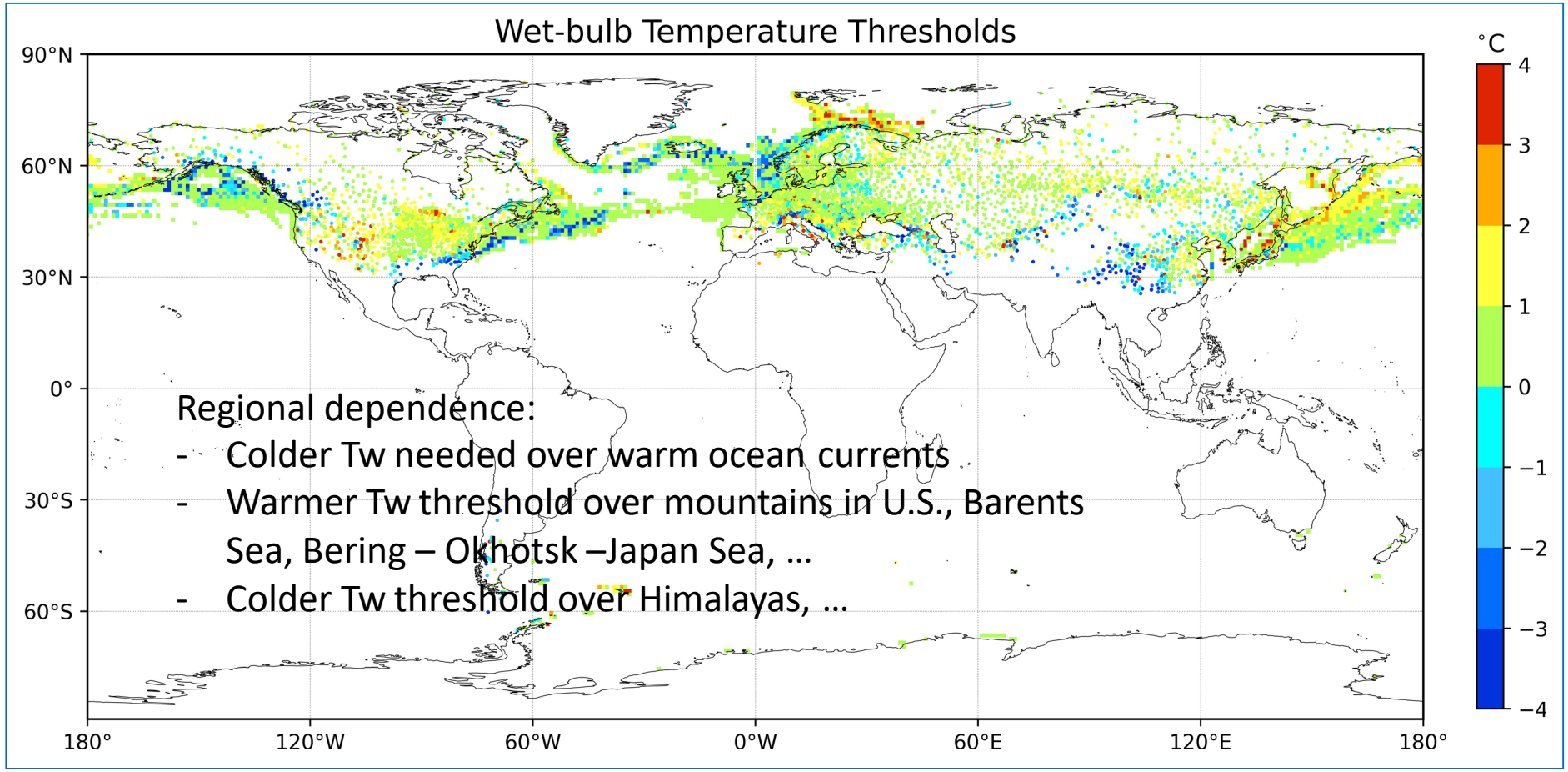
Main Points

- Activity #1: Regional Dependence of Rain-Snow Transition
- Activity #2: Phase Discrimination Assessment
  - Typical phase partitioning is based on near-surface air temperature (e.g. MRMS, GPROF)
  - Either 2 meter Temperature (T-2m) and/or wet bulb temperature (Twb)
  - Accuracy generally increases with finer measurement intervals and humidity information (Twb)
  - Need improved validation datasets
  - Need regional-scale gridded data products
- Activity #3: Passive Microwave Phase Discrimination Assessment
- Explored avenues:
  - Atmospheric modeling which includes microphysical schemes (Reeves et al. 2016; Lis et al. 2020).
  - Satellite observations
  - Starting to explore near-surface precipitation-phase observations
- Slack channel on precipitation-phase-discrimination

Activity #1: Regional Dependence of Rain-Snow transition

(Contributed by Guosheng Liu)

This map shows the wet-bulb T at which precip has 50% prob to be solid. Based on multi-decades of station/ship data



While on average the rain-snow transition occurs around 0.5℃ wet-bulb temperature, regional variation can be as large as ± 3 ℃ !

Possible factors:

1. Lapse rate
2. Surface skin temp.
3. Elevation/pressure
4. $T_{2m} - T_{skin}$
5. …

Need careful studies!

Validation Network and GV-MRMS Data Workshop

Leads & Instructors: Patrick Gatlin and Pierre Kirstetter

Date: 20-August-2020 (During PSD WG Monthly Meeting)

Purpose: Provide "How to get started using VN and GV-MRMS data" Overview

Validation Network Outline:

- What is the VN?
- Which ground radars (GRs) are in the VN
- Retrieved GR geophysical variables
- "100-in-100" criterion
- What information is in the Match-up files?
- Example of Matched GR and DPR data
- Python Notebook to Access VN data
- Links to:
  - VN matchup files on GHRC Archive
  - VH matchup Python Notebook
  - VN users manual
  - VN Ground & Space Radar Volume Matching code

GV-MRMS Outline:

- Overview of Multi-Radar Multi-Sensor (MRMS) System
- Ground Validation (GV)-MRMS is derived from MRMS
- Converting satellite data from orbital Level-2 to gridded Level 3
- What information is in the GV-MRMS files?
- Links to GV-MRMS data files on GHRC Archive

Future VN Training

Want to present cloud-based VN database and some new additions to the VN matchups.
Need to wait for AIST-funded (NASA Marshall) cloud-based project is ready for prime time (still scrutinizing the new vertical motion field in the cloud-based VN).

Backup Slides (from 15-October PSD WG Telecon)

Blind Zone Assessment

- Have identified some relevant past work based on surveying literature, including correction methods used in ground radars with blockage
- PMM team has done and is doing significant work in comparing DPR and other radars to assess Blind Zone conditions and resulting errors
- The work highlighted here is continuing and should lead to better understanding of the problem, addressing the following, for example:
  - In what situations does DPR miss data?
  - How does this affect the DPR and GPM products?
  - How could the missing data be “filled in”?
  - Can we build enough data with ground-based radars to identify the expected vertical reflectivity profile in a sufficient number of situations?
- For V07 we are still mostly in the investigation stage and don’t have algorithms in hand
- The simplest situation is likely weak echoes over ocean, in which ML and radiometer methods could potentially yield an algorithm that could be included in V07

Summary of selected relevant papers to blind zone correction

These studies and others are helping to:

a. Quantify situations that produce a Blind Zones

b. Quantify errors due to the Blind Zones, and

c. Develop statistics that future algorithms could use to detect and correct Blind Zone affected data

Clutter estimation and subtraction

- **GPM DPR: T. Kubota, et al**, 2016: A statistical method for reducing sidelobe clutter for the Ku-band precipitation radar on board the GPM *Core Observatory*. *J. Atmos. Oceanic Technol.*, **33**, 1413–1428.
- **CloudSat: S. Tanelli et al**, 2008: Reducing surface clutter in Cloud Profiling Radar data, based on very high resolution estimate of ocean clutter profile and subtraction from data. NASA Tech Briefs, December, p. 6.

Clutter estimation and subtraction

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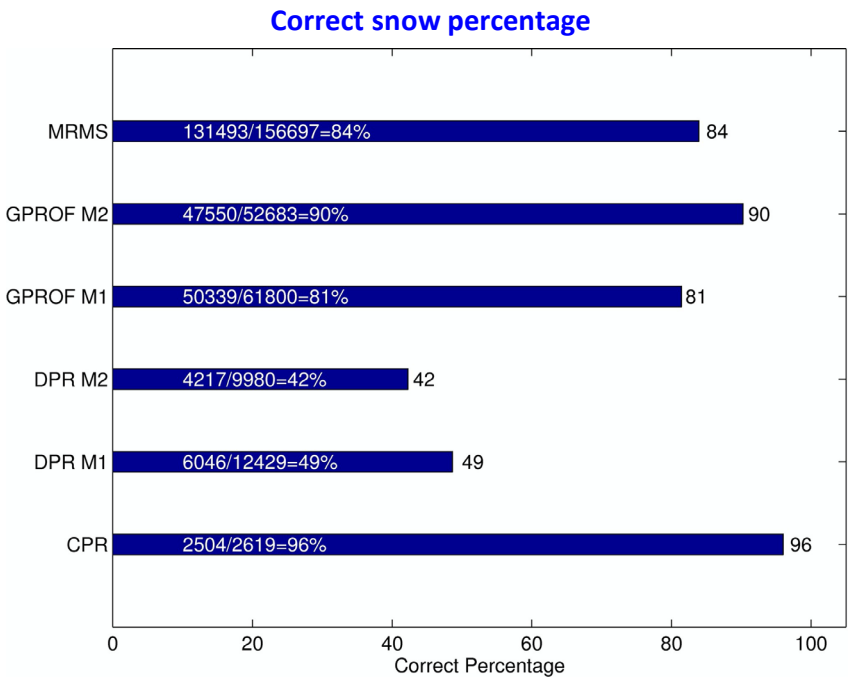
- **CloudSat: S. Tanelli et al**, 2008: Reducing surface clutter in Cloud Profiling Radar data, based on very high resolution estimate of ocean clutter profile and subtraction from data. NASA Tech Briefs, December, p. 6.

Extrapolation, estimation from statistics, etc.

- **Arulraj and Barros**, 2017, 2019. Shallow precipitation, and precipitation in complex terrain; extension of clutter-free echoes to surface.
- **Arulraj 2020**, Precipitation detection improvement based on ML training with HRRR model runs.
- **Bellon et al.**, 2005: Error Statistics of VPR Corrections in Stratiform Precipitation, JAM 44, p. 998. example of using expected profile in stratiform rain to correct measurements.
- **Chen et al**, 2020: Improving Operational Radar Rainfall Estimates Using Profiler Observations Over Complex Terrain in Northern California. IEEE TGRS 58, p. 1821. Example of using additional information to fill in the missing profiles due to beam blockage in ground-based radar.
- **Chen et al.**, 2019: A Flexible Bayesian Approach to Bias Correction of Radar-Derived Precipitation Estimates over Complex Terrain: Model Design and Initial Verification. JHM 20, p. 2367. Bayesian framework for filling in missing data.
- **Wen et al**., 2016: Evaluation of a Method to Enhance Real-Time, Ground Radar–Based Rainfall Estimates Using Climatological Profiles of Reflectivity from Space. JHM 17, p.761. Uses TRMM-estimated VPR to correct ground-based radar in mountainous areas.
- **Rudolph and Friedrich**, 2014: Dynamic and Thermodynamic Predictors of Vertical Structure in Radar-Observed Regional Precipitation. J. Climate 27. p. 2143. Use large scale variables to estimate expected VPR.
- **Geiss and Hardin**, 2020: Adversarial Learning Based Mitigation of Blind Zone and Blockage Regions for Radar. Presentation to PSDWG, July 16th. Train a GAN to fill in missing data

Activity #2: Phase Discrimination Assessment

(Contributed by Yalei You)



Method

- This is not a detection assessment since different instruments have different detection limits.
- Instead, we compute the correct snow (rain) percentage using NCEI Integrated Surface Database (ISD), weather reports from over 35,000 stations worldwide.
- For example: when both CPR and ISD indicate surface precipitation, the correct snow percentage is: # of snow from CPR/# of snow from ISD.

Findings

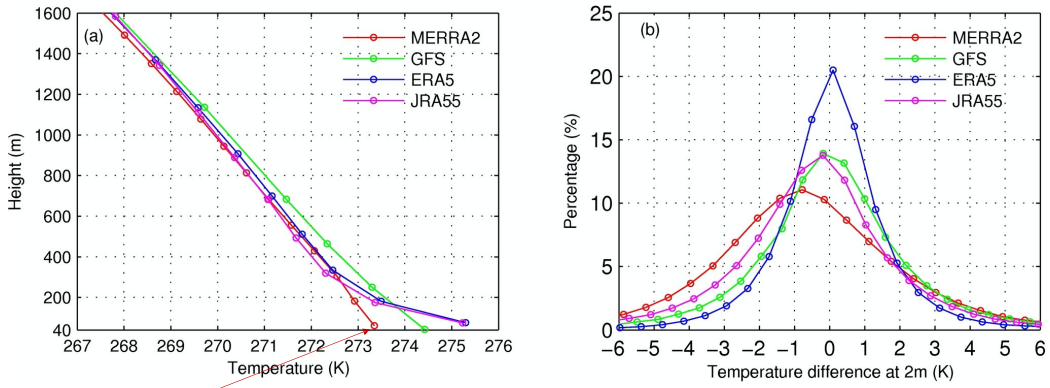
- CloudSat product performs the best, partially due to
    - ECMWF temperature lapse rate
    - Mixed precipitation category
- DPR provides the phase at about 1.5 km, not the surface
- MRMS mis-identifies snow as “cold stratiform” (identified in Chen et al. 2016)
- GPROF: rain and snow in the same a priori database

Phase Discrimination Assessment

(Contributed by Yalei You)

Correct percentage from four reanalysis datasets (Method: wet-bulb temperature at 2m, Sims and Liu, 2015)

	MERRA2	JRA55	ERA5	GFS
Correct snow percentage	97%	95%	96%	96%
Correct rain percentage	88%	94%	96%	96%



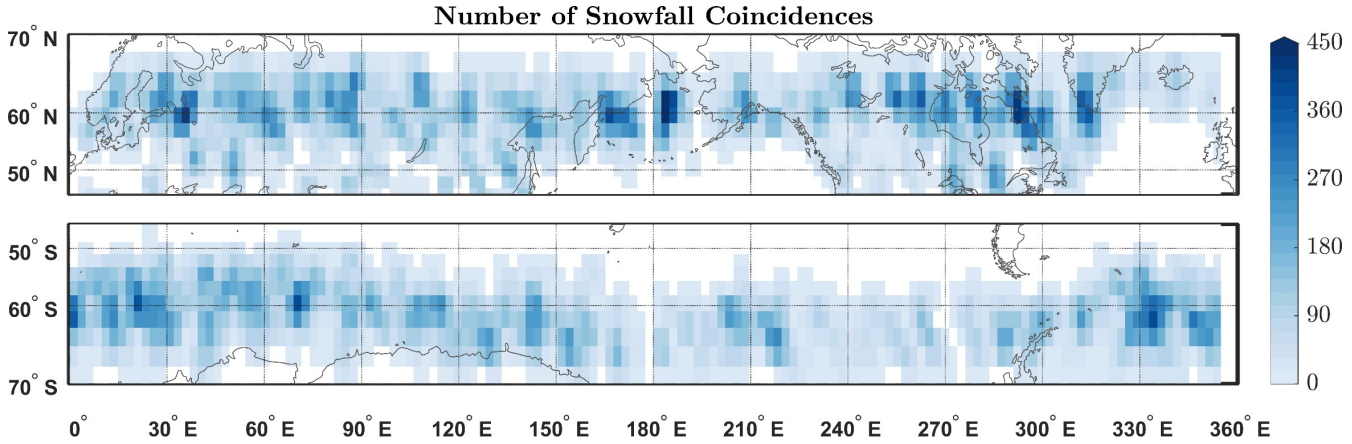
(a)Temperature profiles below 1.6 km from four reanalysis datasets

(b)Histogram of the 2-m temperature difference between surface observations and reanalysis datasets.

- **MERRA2 temperature close to the surface is noticeably colder than other three datasets, leading to more "rainfall" pixels being classified as "snowfall" pixels.**

Activity #3: Passive Microwave Phase Discrimination Assessment

(Contributed by Ardeshir Ebtehaj)

Data

- Three years (2014-2016) of CPR-GMI coincidences as our database
- Using CloudSat products 2C-SNOW, 2C-PRECIP, and 2C-CWC-RO, as well as sea ice concentration and snow depth from AMSR-E/2, and ancillary information such as air temperature from ECMWF.