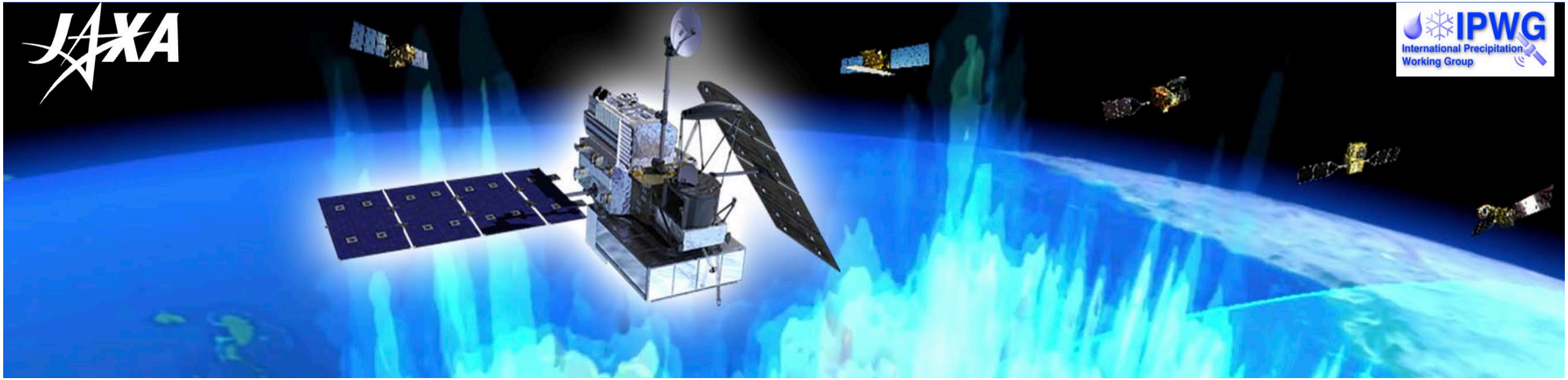

Evaluation of V7 Products and Developing New Features in V8 of Classification Module in GPM DPR Level-2 Algorithm

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15-18 July 2024
Tokyo Institute of Technology
Tokyo, Japan

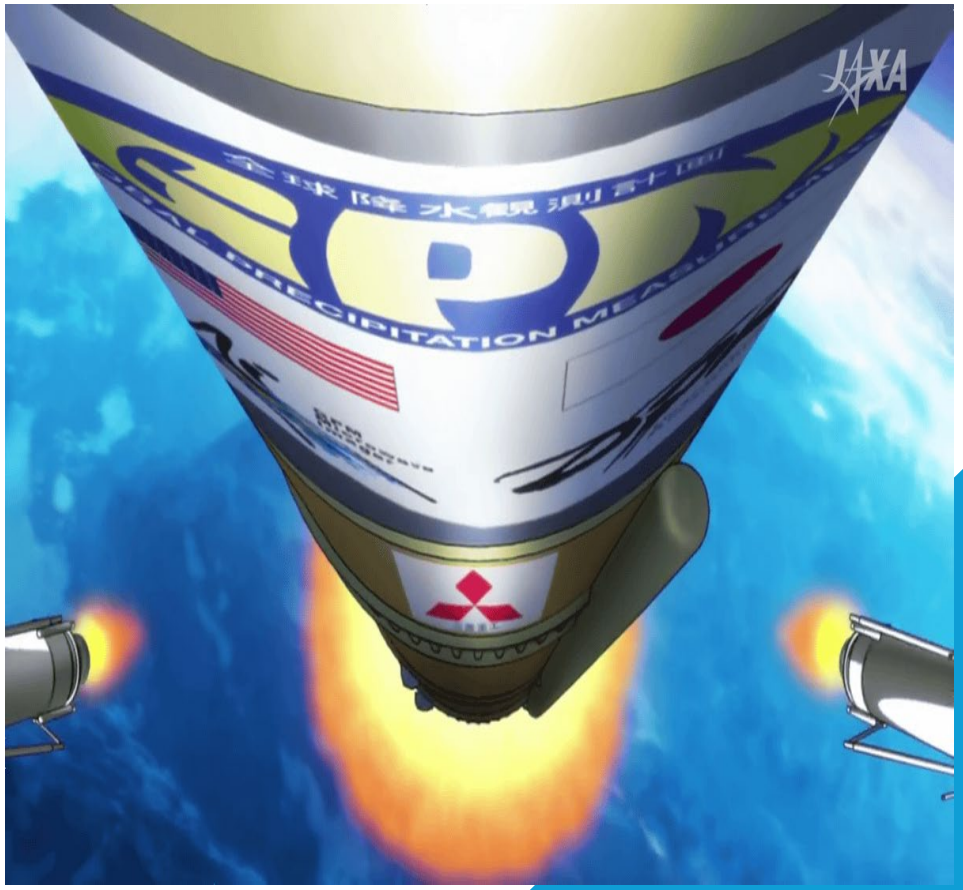
Colorado State University

Outline

- Background.
- Evaluation of V7 Products from Classification Module.
- After GPM boost Evaluation.
- Development of New Feature for GPM DPR level-2 Algorithm in V8.

Background

- GPM DPR changed scan pattern on May 21, 2018.
  - KaPR High-Sensitivity beams scan changed from in the inner swath before May, 2018, to the outer swath and match with KuPR's beams.
- The GPM satellite boosted orbit in Nov,2023 which raised its altitude from 400km to 435km.
- GPM DPR version 8 algorithms are established based on the orbit boosted full swath observations.



Background

Products developed by our team till version 7:

1, “Type”. 2, “MLTop”, “MLBottom”
3, “MLquality” 4, “flagSurfaceSnowfall”
5, “flagGraupelHail” 6, “flagHail”

Hail Identification Algorithm for DPR on board the GPM Satellite, *Journal of IEEE Transactions on Geoscience and Remote Sensing, Volume,* 2023.

Graupel and Hail Identification Algorithm for the Dual-frequency Precipitation Radar (DPR) on the GPM Core Satellite. *Journal of the Meteorological Society of Japan,* 2021.

Ground Validation of Surface Snowfall Algorithm in GPM Dual-Frequency Precipitation Radar. *J. Atmos. Oceanic Technol*, 2019.

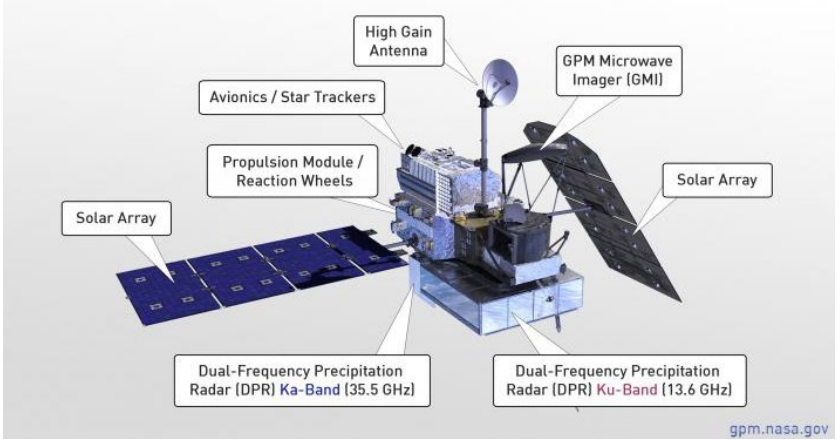
An Algorithm to Identify Surface Snowfall from GPM DPR Observations, *Geoscience and Remote Sensing, IEEE Transactions,* 2017.

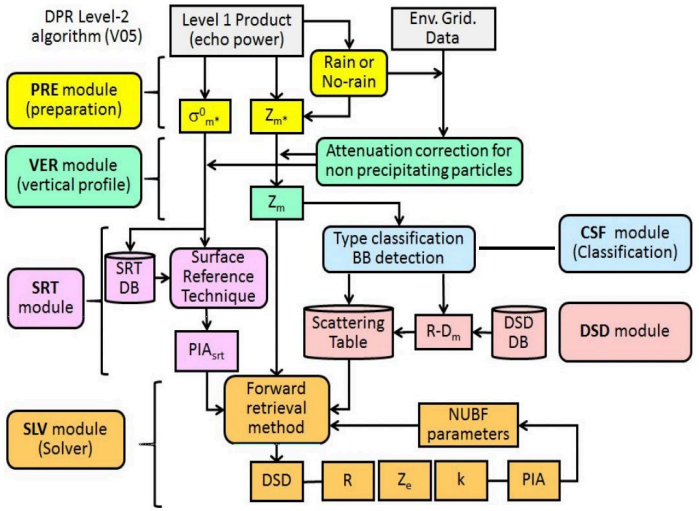
Evaluation and Validation of GPM Dual-frequency Classification Module after Launch, *J. Atmos. Oceanic Technol., Special Collection: Precipitation retrieval algorithms for GPM.* 2016.

An algorithm for drop size distribution retrieval from GPM dual-frequency precipitation radar, *Geoscience and Remote Sensing, IEEE Transactions,* 2014.

Precipitation Type Classification Method for Dual-Frequency Precipitation Radar (DPR) Onboard the GPM, *Geoscience and Remote Sensing, IEEE Transactions* , 2013.

Hydrometeor Profile Characterization Method for Dual-Frequency Precipitation Radar Onboard the GPM, *Geoscience and Remote Sensing, IEEE Transactions*, 2013.



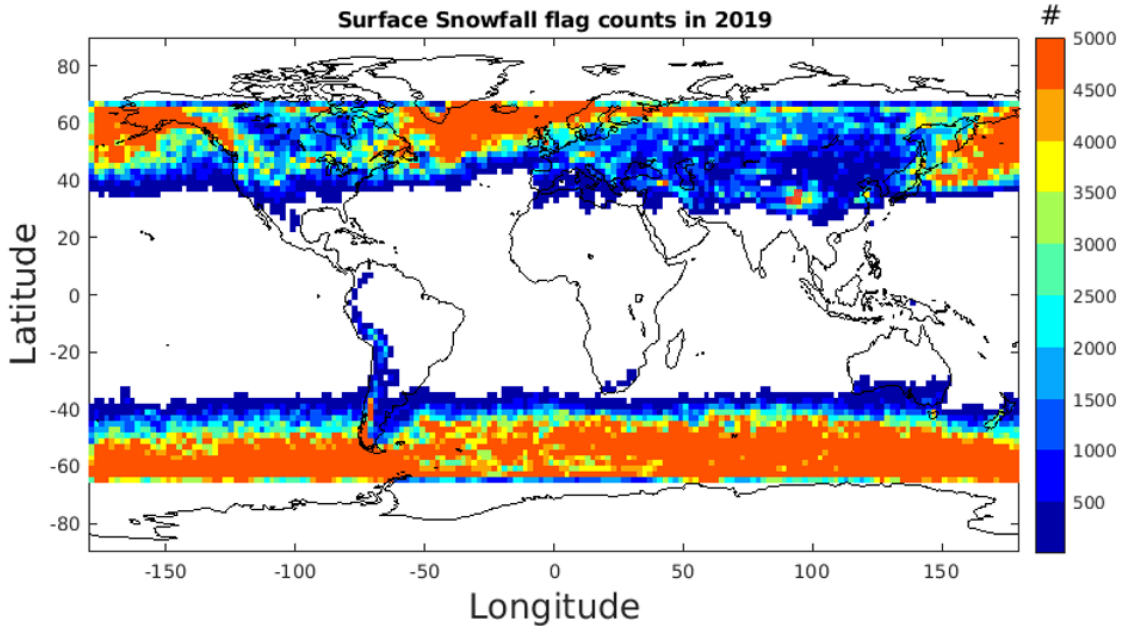


Flowchart of GPM DPR level 2 algorithm
(from GPM DPR ATBD, 2021)

Evaluation of V7 Products

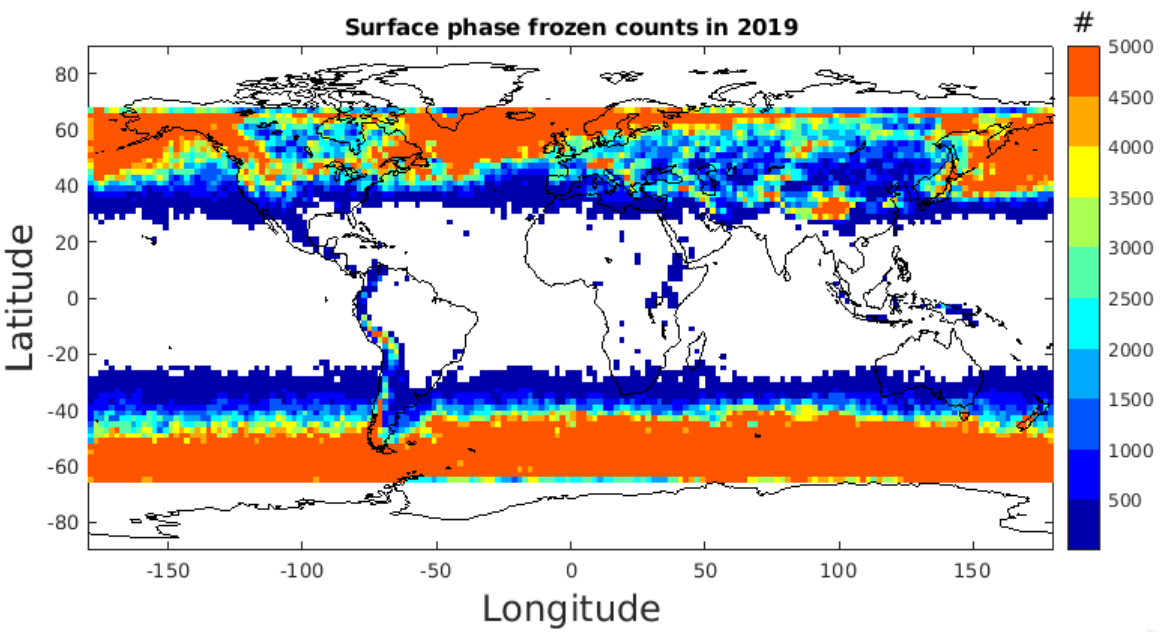
Comparison on “flagSurfaceSnowfall”

Product based on observation



“flagSurfaceSnowfall” flag (Le et al. 2017) in DPR level-2 algorithm

Product Using model

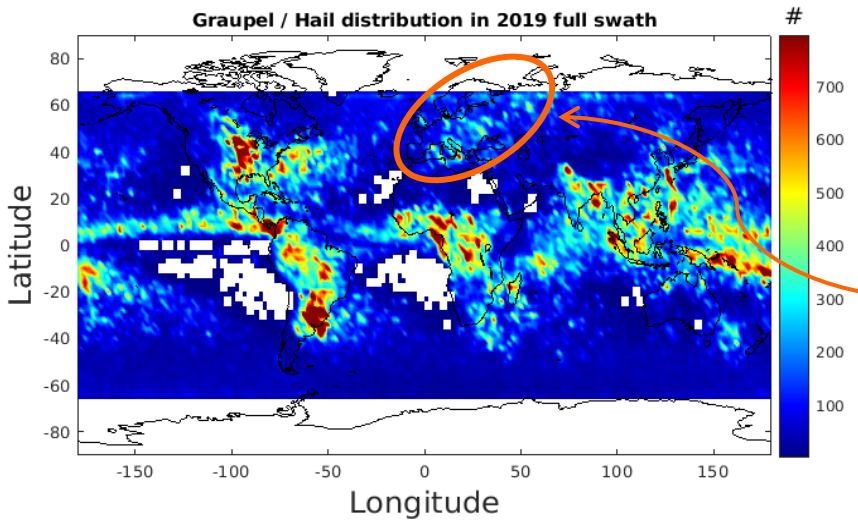


“phaseNearSurface” flag in DPR level-2 algorithm (Iguchi, 2020)

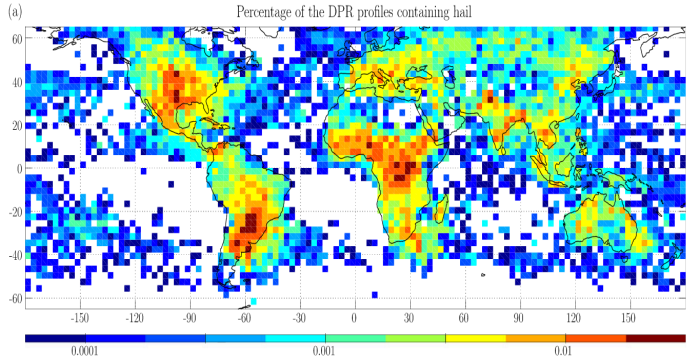
- Over land, both products result in fairly similar snow occurrences, although the “phaseNearSurface” tends to slightly overestimate snowfall compared to the “flagSurfaceSnowfall”.
- Over oceans, both flags are fairly similar although the “phaseNearSurface” flag has more detection of snowfall occurrence at latitudes at (30°–40°) regions.

Evaluation of V7 Products

Comparison on “flagGraupelHail”



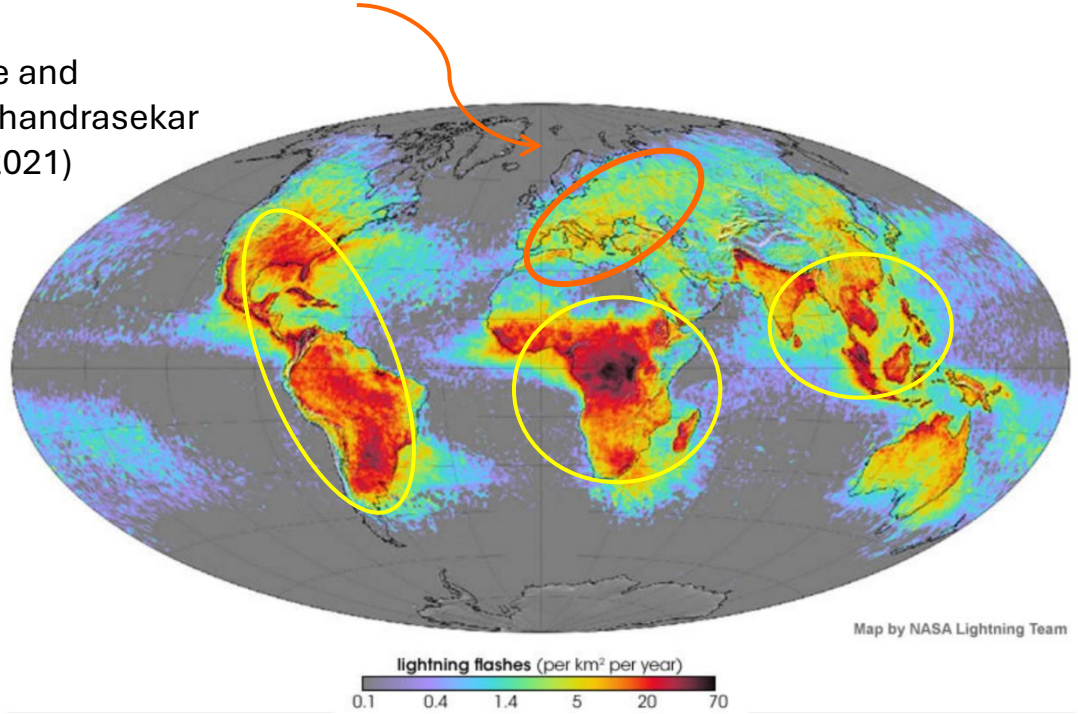
Global distribution of “flagGraupelHail” count mapping to the 2° x 2° Lat / Lon box for year 2019.



Global map of the fraction of the DPR profiles that contain hail based on combined method of radar and radiometer of GPM from year 2014 to 2016 using 3° grid. (Mroz et al, 2017)

- active lightning regions are believed to be associated with the existence of graupel at high altitudes.
- Good association can be found at circled areas between these two maps.
- **Improved detection in Europe area with full swath data.**

Le and Chandrasekar (2021)



World Lightning Map: The map above shows the average yearly counts of lightning flashes per square kilometer based on data collected by NASA's Lightning Imaging Sensor on the Tropical Rainfall Measuring Mission satellite between 1995 and 2002. Places where less than one flash occurred (on average) each year are gray or light purple. The places with the largest number of lightning strikes are deep red, grading to black. (This Map is made by NASA Lighting Team).

Evaluation of V7 Products

Comparison on “flagHail” product with Technique 1
Based on max reflectivity statistics

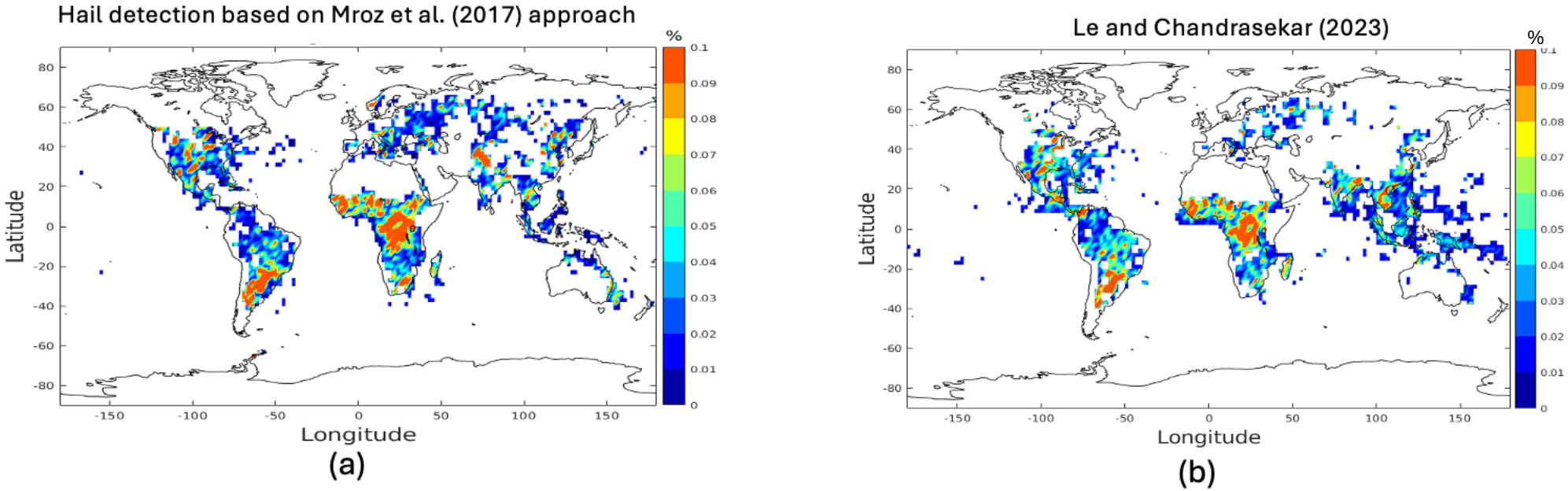
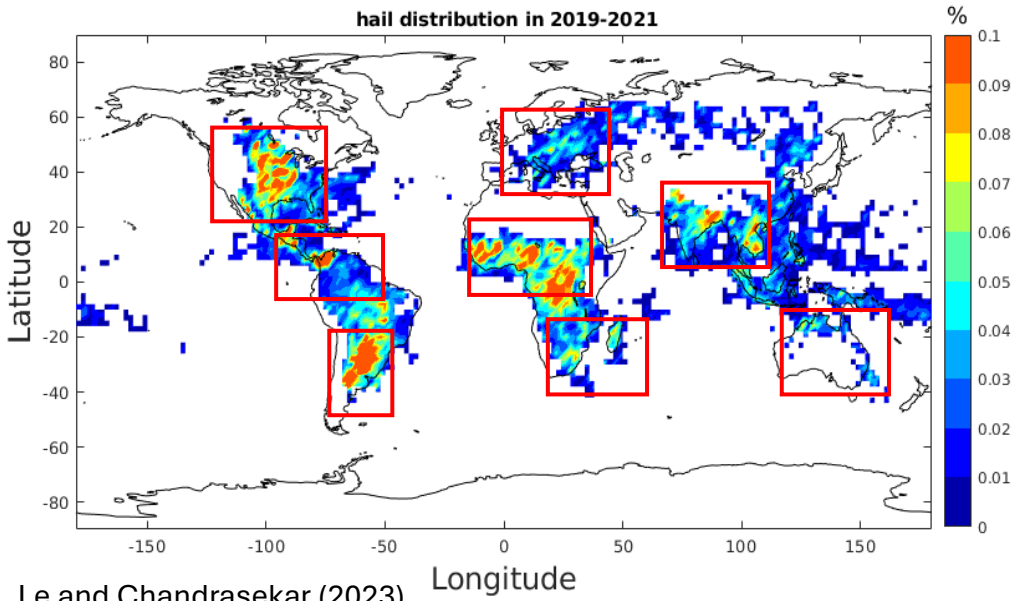


Figure illustrate this hail distribution using full year data from 2021. (a) is the hail distribution using Mroz et al. (2017) method and (b) is the distribution using our algorithm. From virtual comparison, in general, hail counts peak align well from both algorithms. Our algorithm detects more hail in the central America and south Asia while Mroz et al. (2017) detects more hail in the northern Europe.

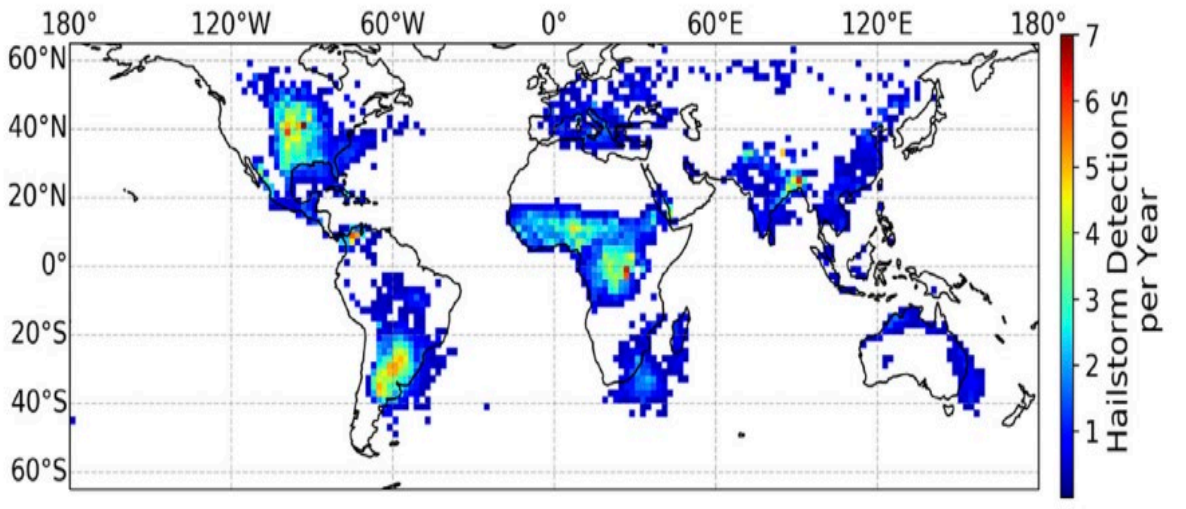
Evaluation of V7 Products

Comparison on "flagHail", Radiometer based Technique 2 Using GMI brightness temp



Le and Chandrasekar (2023)

(a)



Battaglia et al. (2022) GMI based approach (b)

Figure (a) Global distribution of "flagHail" counts on a 2° by 2° lat/lon grid over globe using GPM DPR full swath data from year 2019~2021. (b) Same figure as Fig.9.10 from Battaglia et al. (2022). Hail climatology based on the approach of Bang and Cecil (2019), as applied to both the TMI and GMI (TRMM and GPM Microwave Imager).

Hot spots:

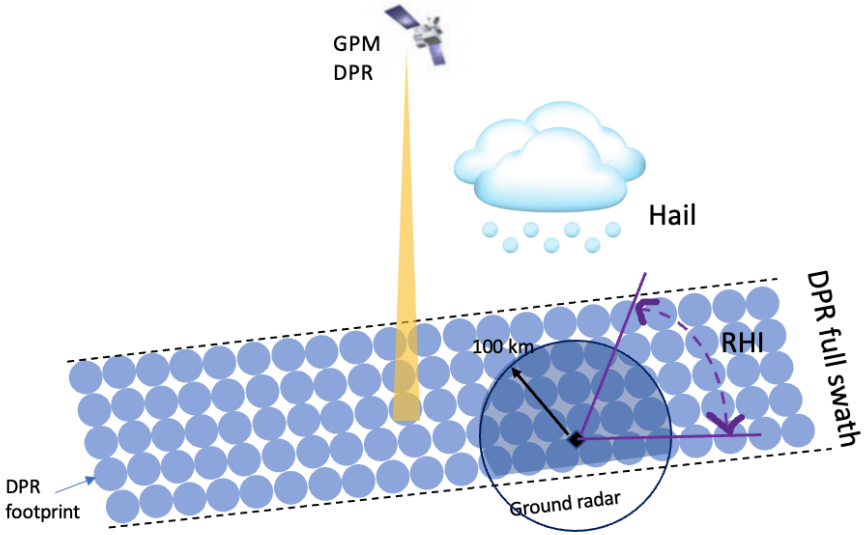
- The map clearly shows the importance of orography and land-sea contrast in hail formation. Most of the hail events occur over land and over regions adjacent to the land.
- Hot spot for hail: The regions having local maxima are Africa region south of Sahel, the subtropical Americas including southern Brazil, northern Argentina and Central United States, foothill of Himalaya region, and northern and eastern Australia. Fewer counts are scattered in northern Asia and extends to southeast of Europe.

Evaluation of V7 Products

Comparison on "flagHail"

Flow chart to perform match ratio calculation between DPR and ground radar.

Quantitative comparison with NEXRAD radar on a case basis



A cartoon illustration to depict the approach performing quantitative validation between hail identification algorithm and ground radar hydrometeor types.

$$\text{Match ratio} = \frac{\#\text{ of matched DPR footprint}}{\#\text{ of valid DPR footprint overlapping with GR}}$$

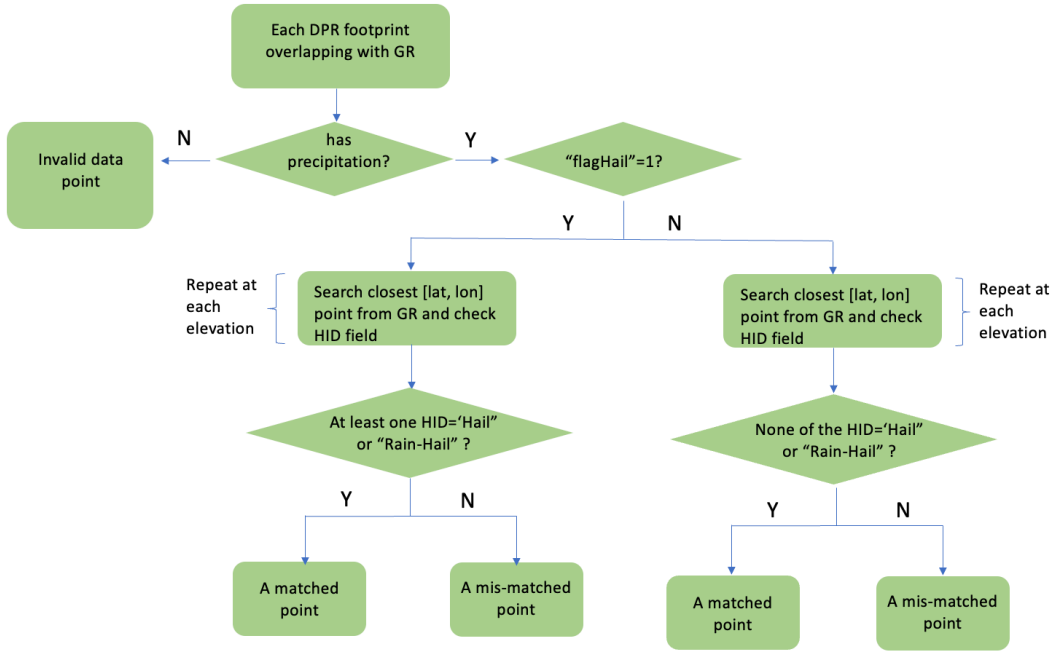


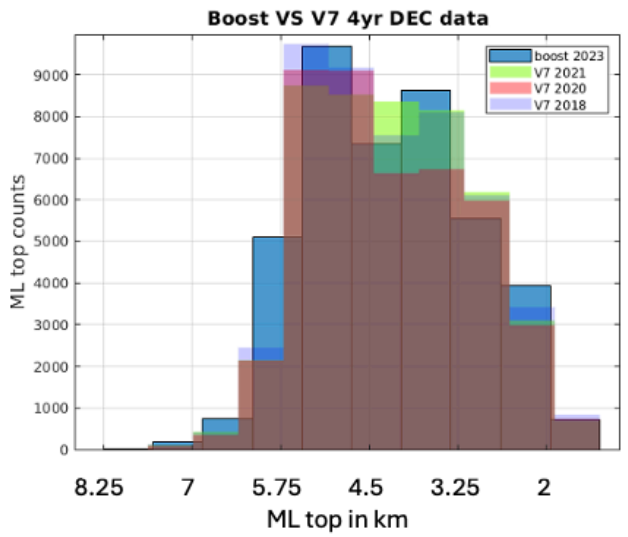
Table Match ratio for six validation cases between DPR and NEXRAD radar.

	KLZK VS DPR orbit 25427	KLNX VS DPR orbit 25028	KFSD VS DPR orbit 24198	KVNX VS DPR orbit 24557	KGLD VS DPR orbit 1518	KFWS VS DPR orbit 519
Location and Time	Little rock, AR 8/20/2018	North Platte, NE 7/25/2018	Sioux Falls, SD 6/2/2018	Vance AFB, OK 6/25/2018	Boarder of CO and KS, 6/5/2014	Dallas Fort Worth, TX, 4/2/2014
Valid data point	606	741	1054	581	788	623
Matched data point	532	731	1019	545	745	577
Match ratio	**87.8%**	**98.6%**	**96.7%**	**93.8%**	**94.5%**	**92.6%**

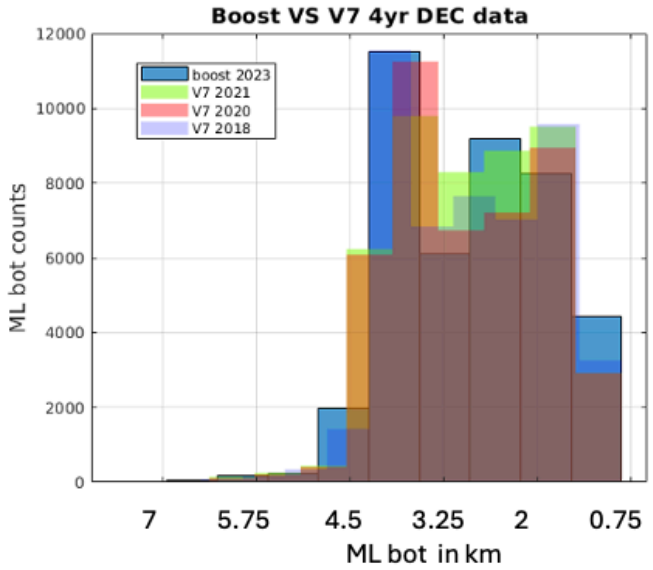
After GPM Boost Evaluation

- Boost data comes from https://pps.gsfc.nasa.gov/itedata/GPM702/ for year 2023.
- Comparison use **December** data from boost(2023), and V7 data from year2021, year 2020 and year 2018.

Distribution of ML top index between 4 years data



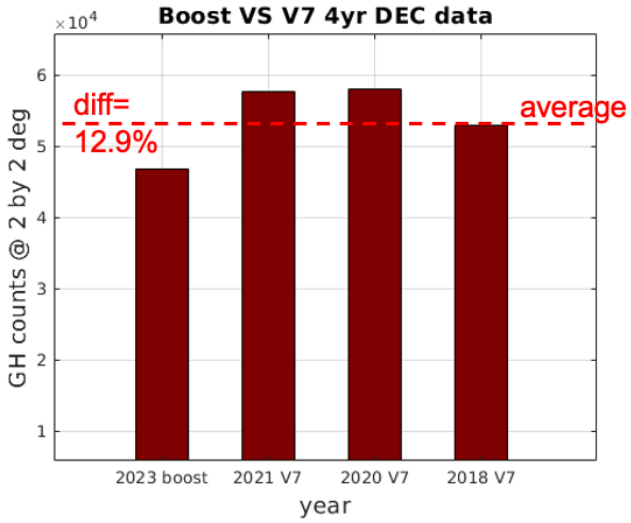
Distribution of ML bottom index between 4 years data



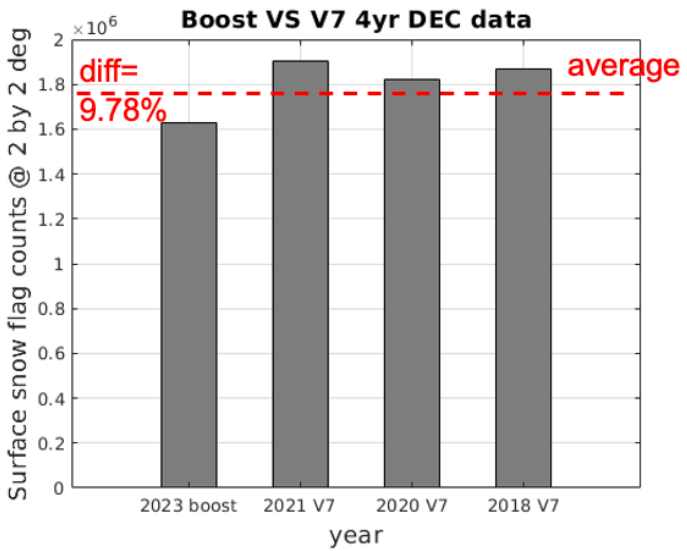
After GPM Boost Evaluation (within year to year Natural variability)

- Flags comparison between boost data and V7. Flags include “flagGraupelHail”, “flagSurfaceSnowfall”, “flagHail”.
- Boost data comes from https://pps.gsfc.nasa.gov/itedata/GPM702/ for year 2023.
- Comparison use **December** data from boost(2023), and V7 data from year2021, year 2020 and year 2018.

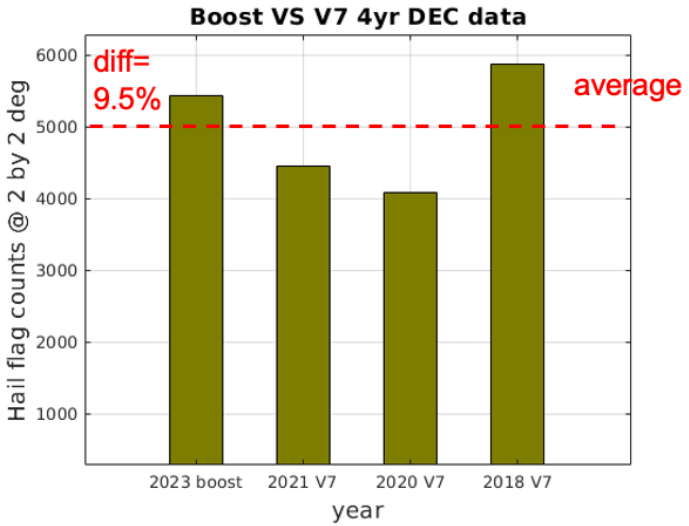
“flagGraupelHail”



“flagSurfaceSnowfall”



“flagHail”

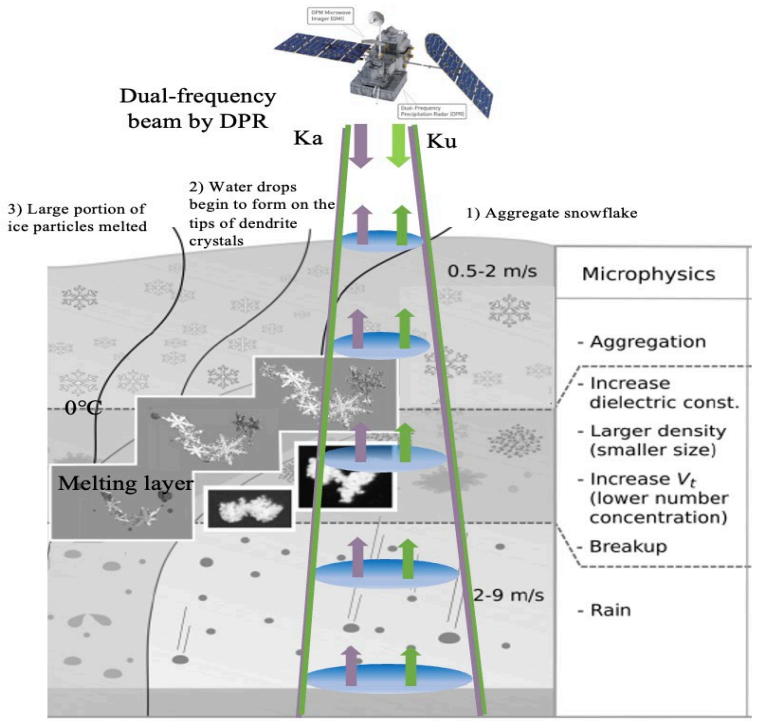


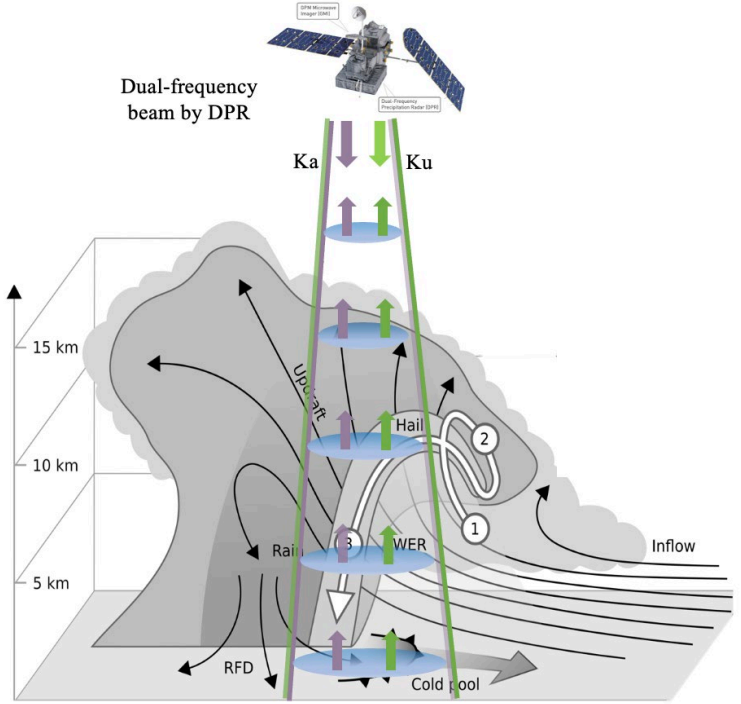
- Initial test illustrates reasonable comparisons between boost data and V7 data. The difference between boost year data and V7 data are all within or around 10% in average sense. The distribution of the Melting layer top and bottom index have similar shapes for boost data and V7 data. Opposite trend in flag counts for “flagHail” and “flagGraupelHail” indicates the difference comes from year-by-year variation, rather than the algorithm due to boost.

New Feature for V8

New feature of **Version 8** for GPM-DPR algorithm

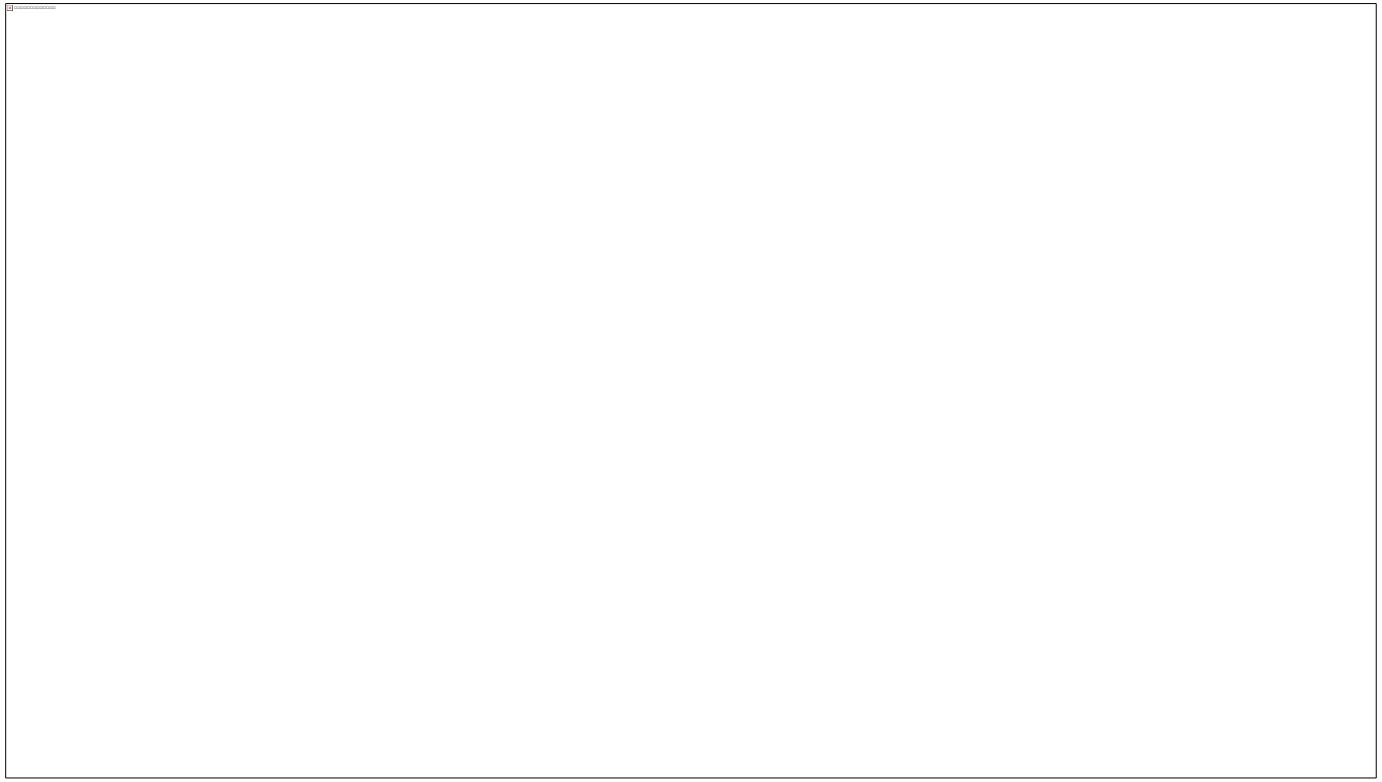
Hydrometeor identification for DPR resolution





Conceptual plot for GPM DPR overlooking a Left: stratiform storm featuring snow, melting layer and rain on vertical profile. Right: hailstorm on vertical profile. (Chandrasekar et al. 2021)

ALGORITHM



- In the initial phase, five hydrometeor types will be introduced. They are dry snow/ice crystal (DS/ICE), wet snow (WS), graupel (GPL), hail (Hail) and rain (Rain).
- DS/ICE, GPL and Hail represent low-density, medium-density, high-density particles respectively.

- ❑ The judgements are made mainly on the DPR products developed by our team as listed in the “algorithm judgement box”.
- ❑ Mixed phase hydrometeors are judged with melting layer top and bottom together with the 0 isotherm.
- ❑ Flag of surface snowfall is used to identify snow only profile, while flags for detecting rain, wet snow, graupel and hail help identify range bins with those hydrometeor types.
- ❑ The whole judgement box is a robust detection system to not only combine the products but enforce meteorologically meaningful.

VALIDATION ACTIVITIES

NASA NPOL radar

C-pol radar

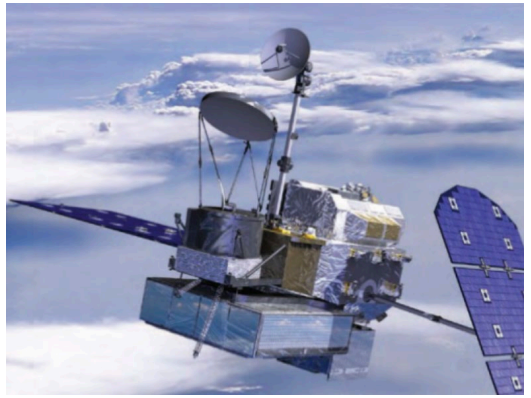
"Champion hail" cases)

HYDROMETEOR IDENTIFICATIOM

Ground hail report

NEXRAD radar network

GMI-based HID

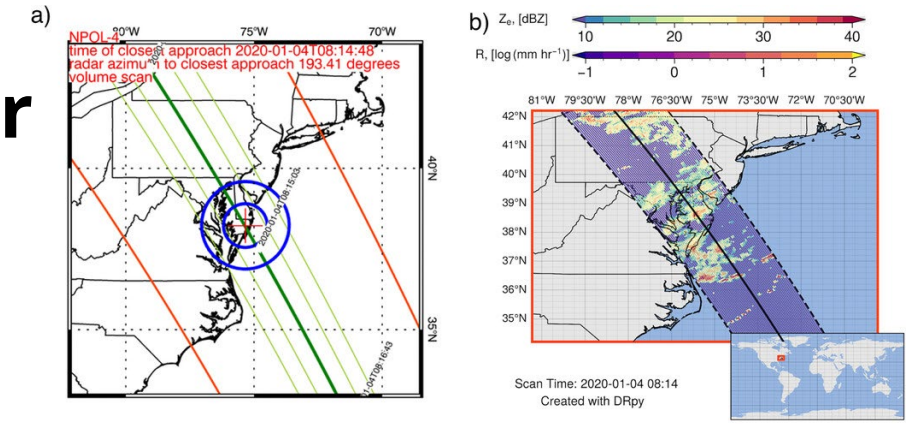


VALIDATION with NPOL radar

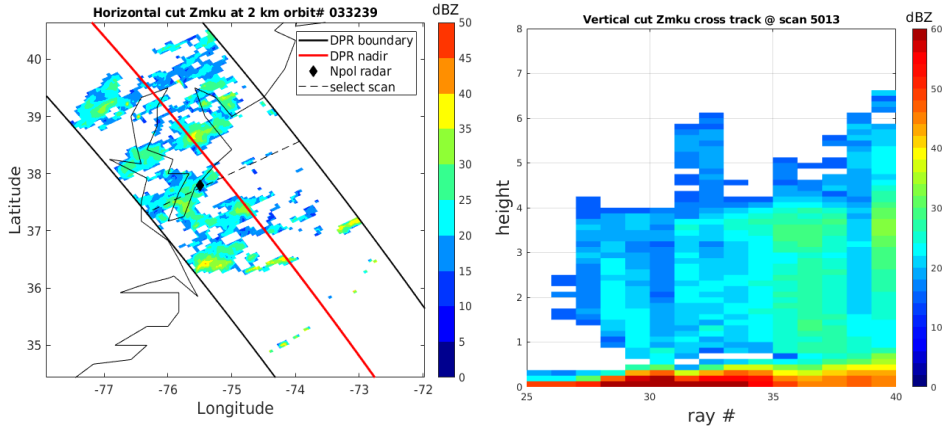
Case 1 (2020-01-04)

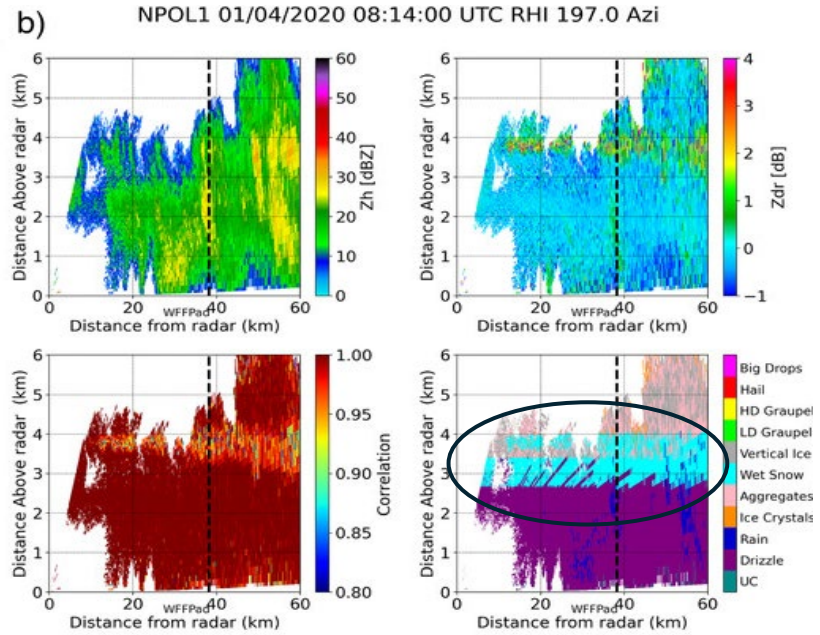
GPM Core Observatory satellite overpass orbit track in (a) 0814 UTC 4 Jan 2020 with GMI (red), DPR Ku (outer) and Ka (inner) swath lines (green), and NPOL 75 km and 150 km range rings (blue). DPR version 6A near-surface Ze and R created Chase (2022) are shown in (b) for the cases.

Pabla, C. S., D. B. Wolff, D. A. Marks, S. M. Wingo, and J. L. Pippitt, 2022: GPM Ground Validation at NASA Wallops Precipitation Research Facility. *J. Atmos. Oceanic Technol.*, **39**, 1199–1215

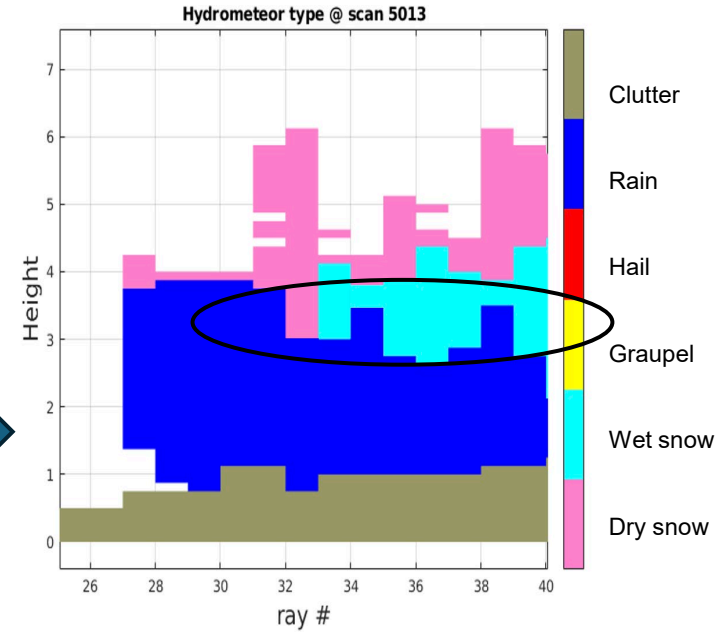


DPR observation and hydrometeor identification





Same melting layer height between 3-4 km

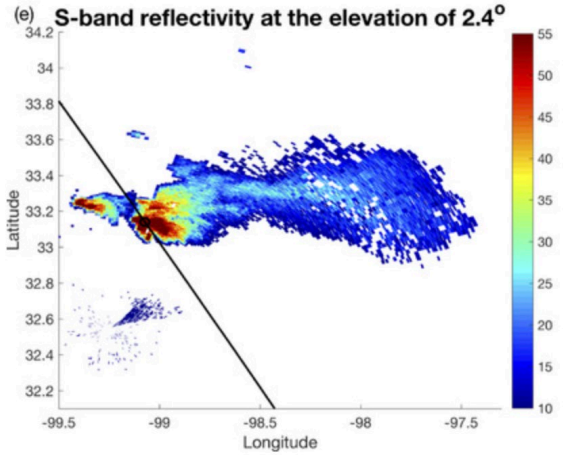


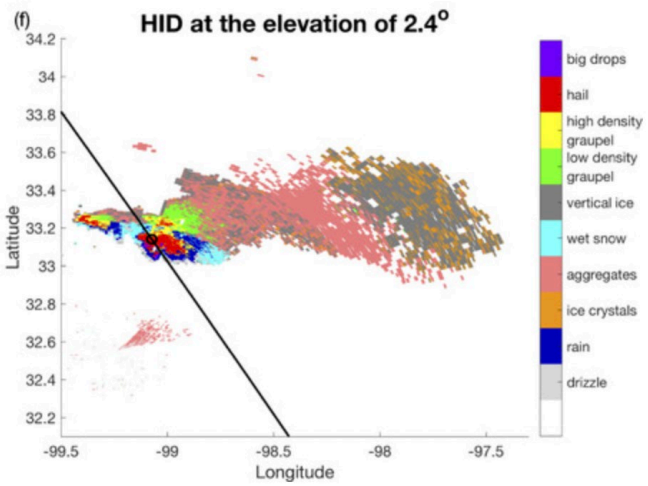
NPOL 197° RHI reflectivity (Zh), differential reflectivity (Zdr), correlation (phv, and hydrometeor identification (HID) The dotted vertical line near 40 km represents WPRF.

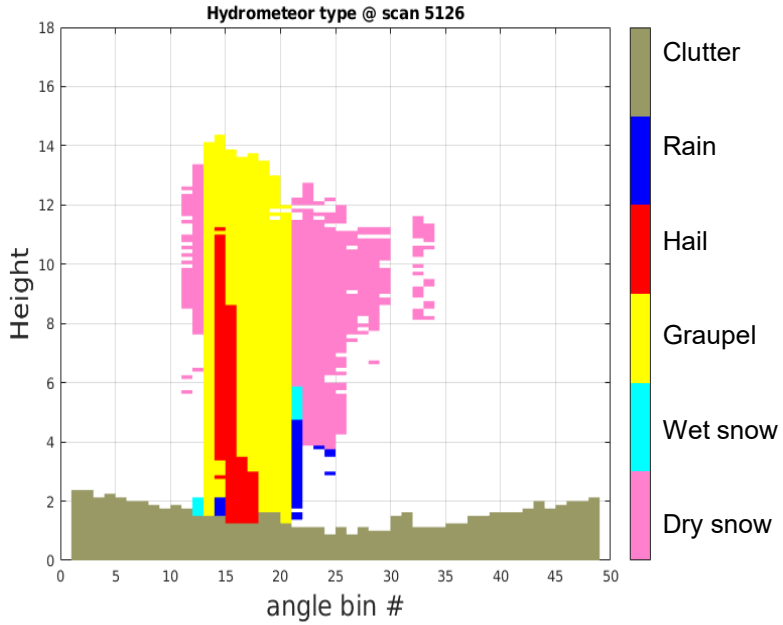
VALIDATION with NEXRAD radar

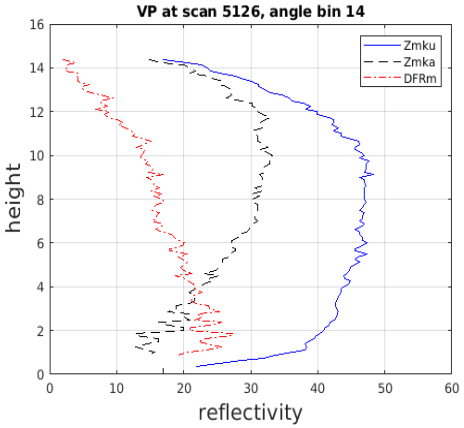
- Hailstorm captured by KFWS radar (West of Dallas) and GPM DPR on 04/02/2014.

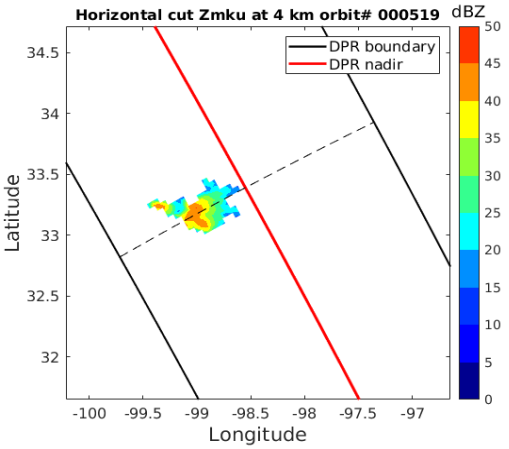
GR plot from Mroz et al. (2018). HID from Dolan et al. (2013)

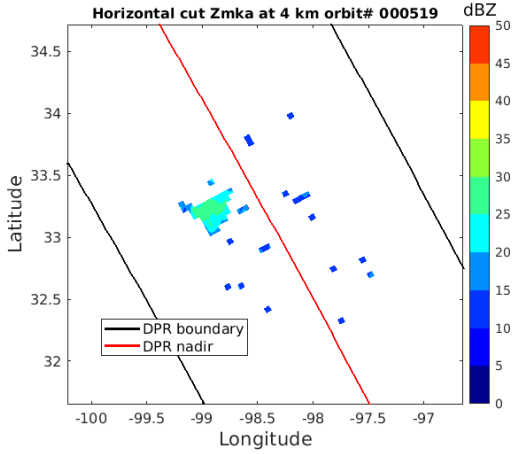


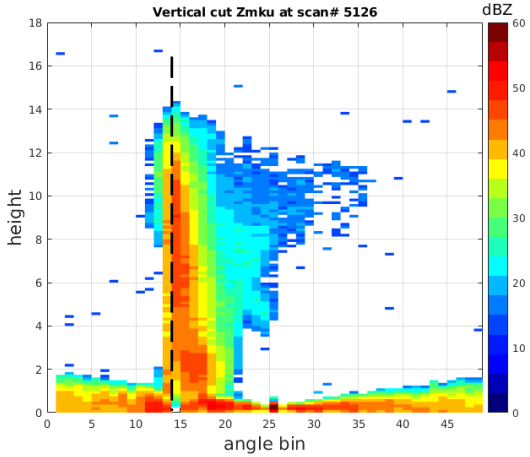


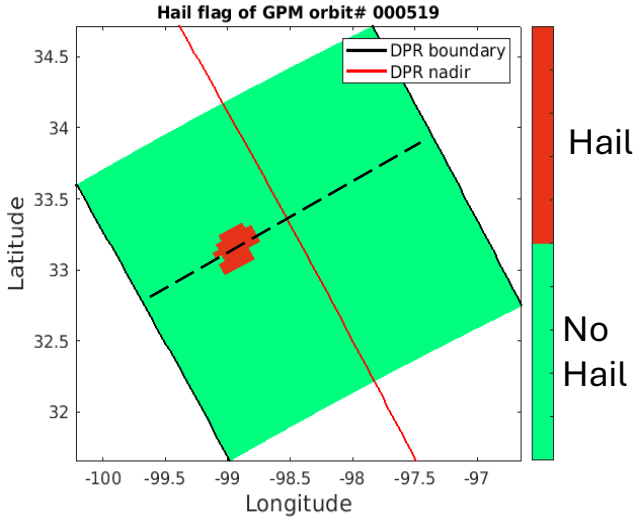










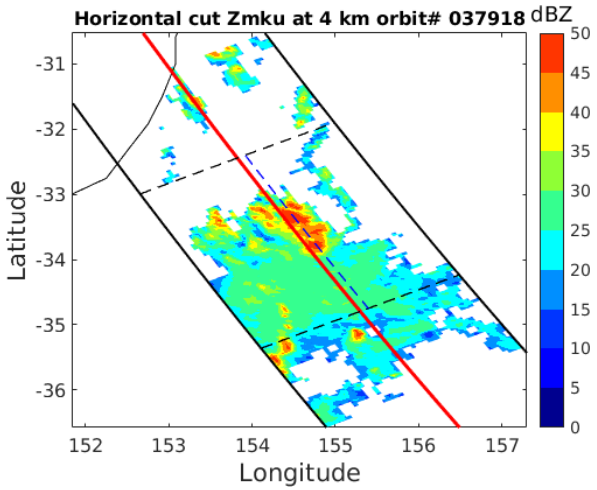


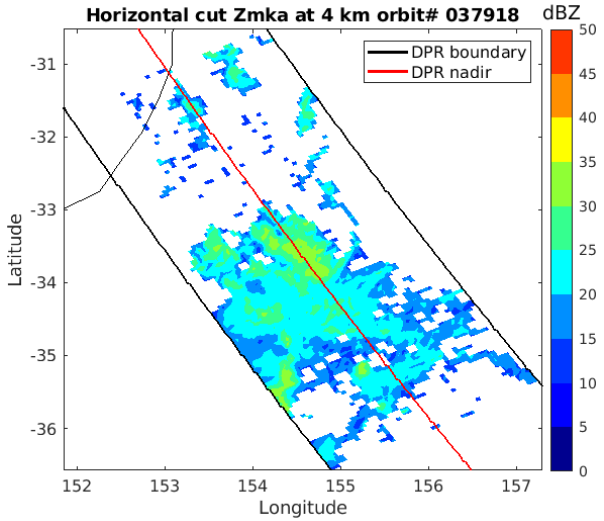
VALIDATION WITH CHAMPION HAIL CASE

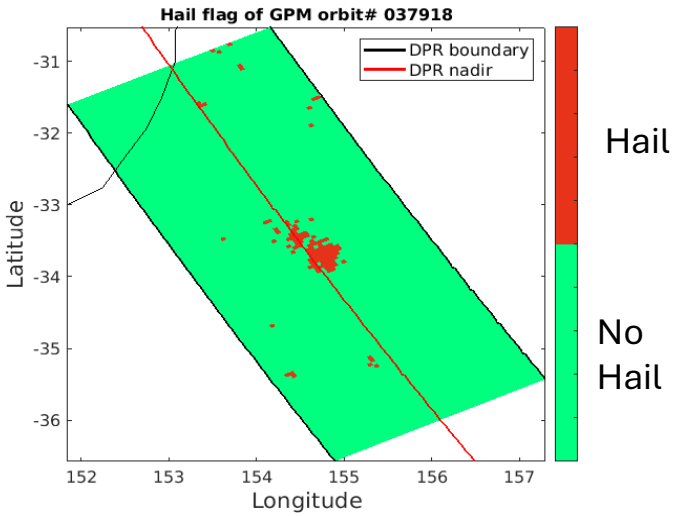
GMI based “Champion hail cases” are listed in Battaglia et al. (2022).

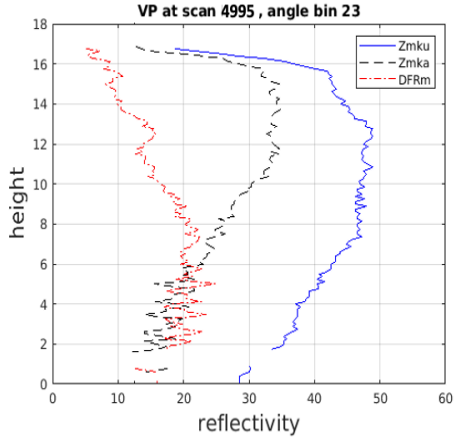
- East of Sydney, Australia, 10/31/2020, DPR orbit 37918

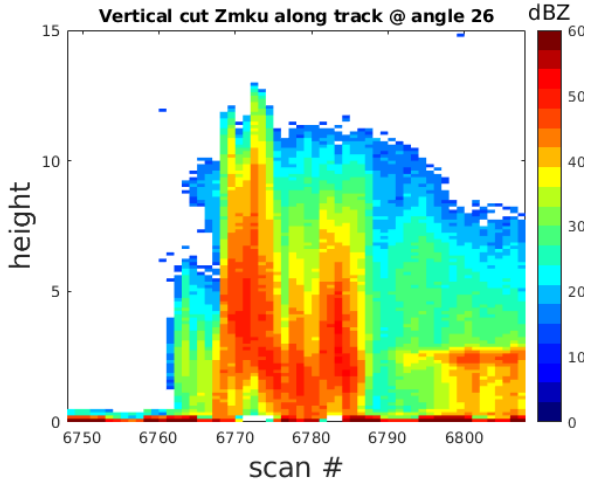
Alessandro Battaglia, Kamil Mroz, Daniel Cecil,Chapter 9 - Satellite hail detection, Editor(s): Silas Michaelides,Precipitation Science,Elsevier,2022,Pages 257-286.

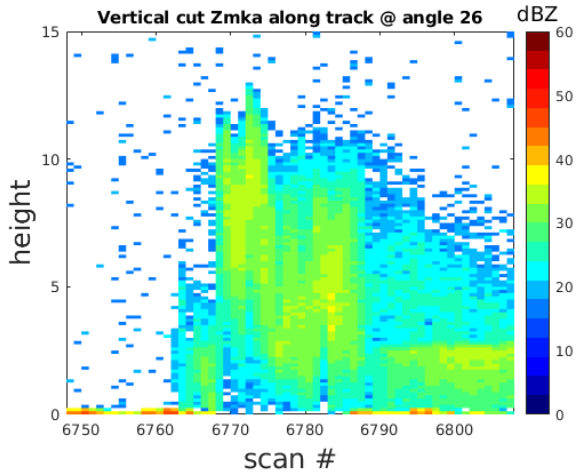


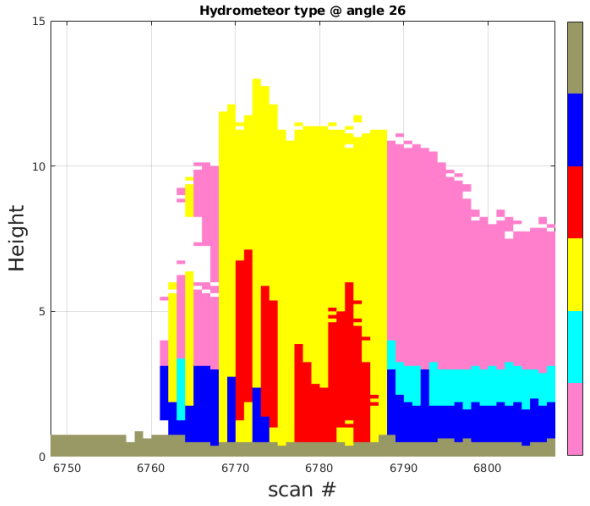


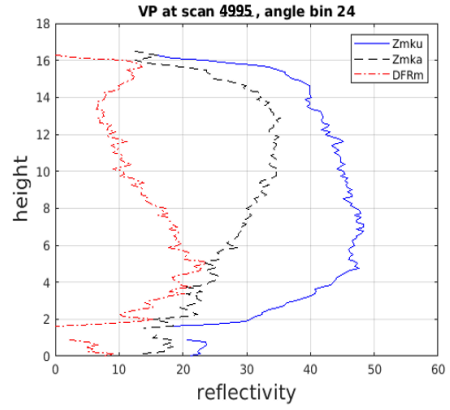










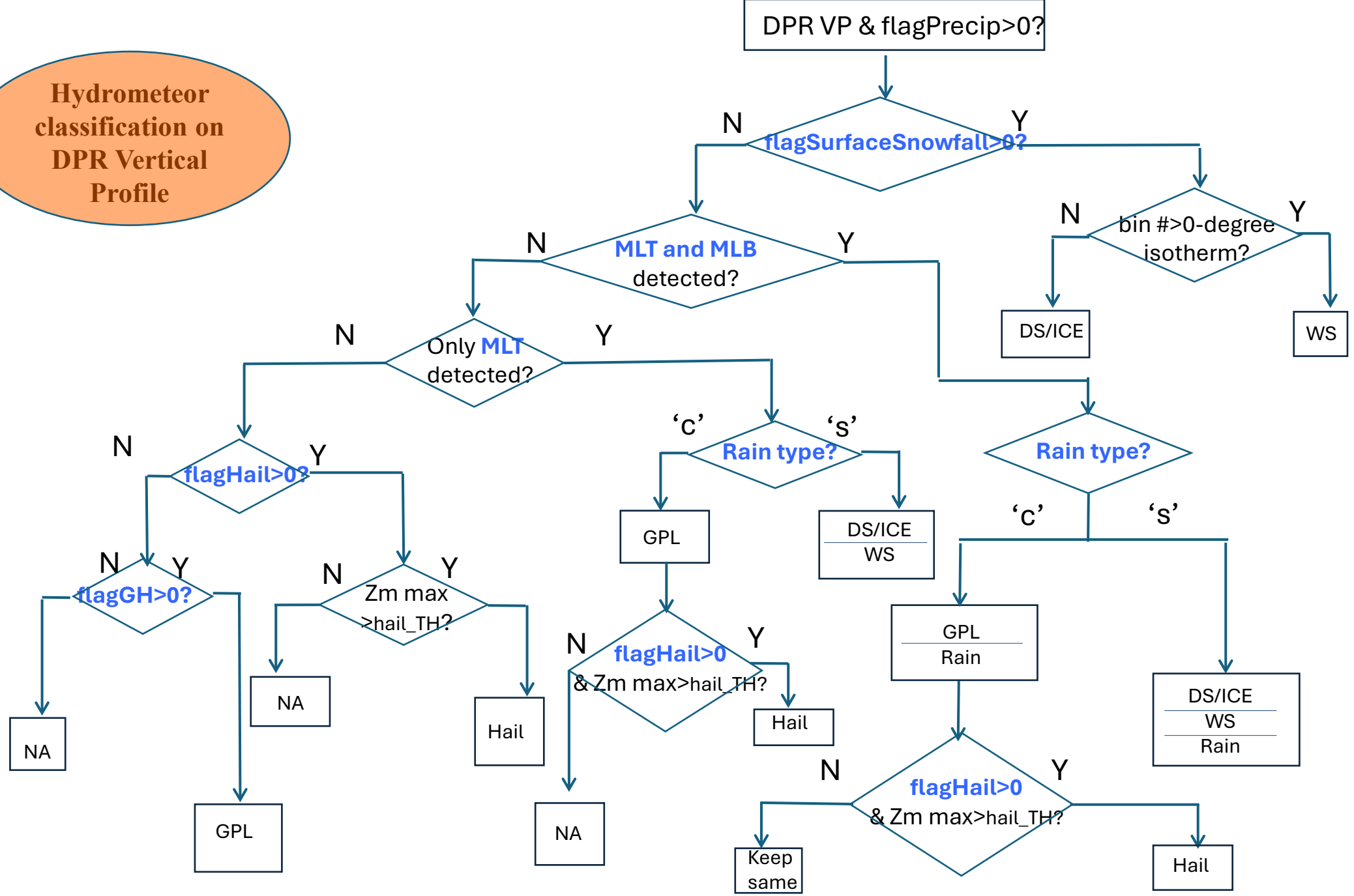


Summary

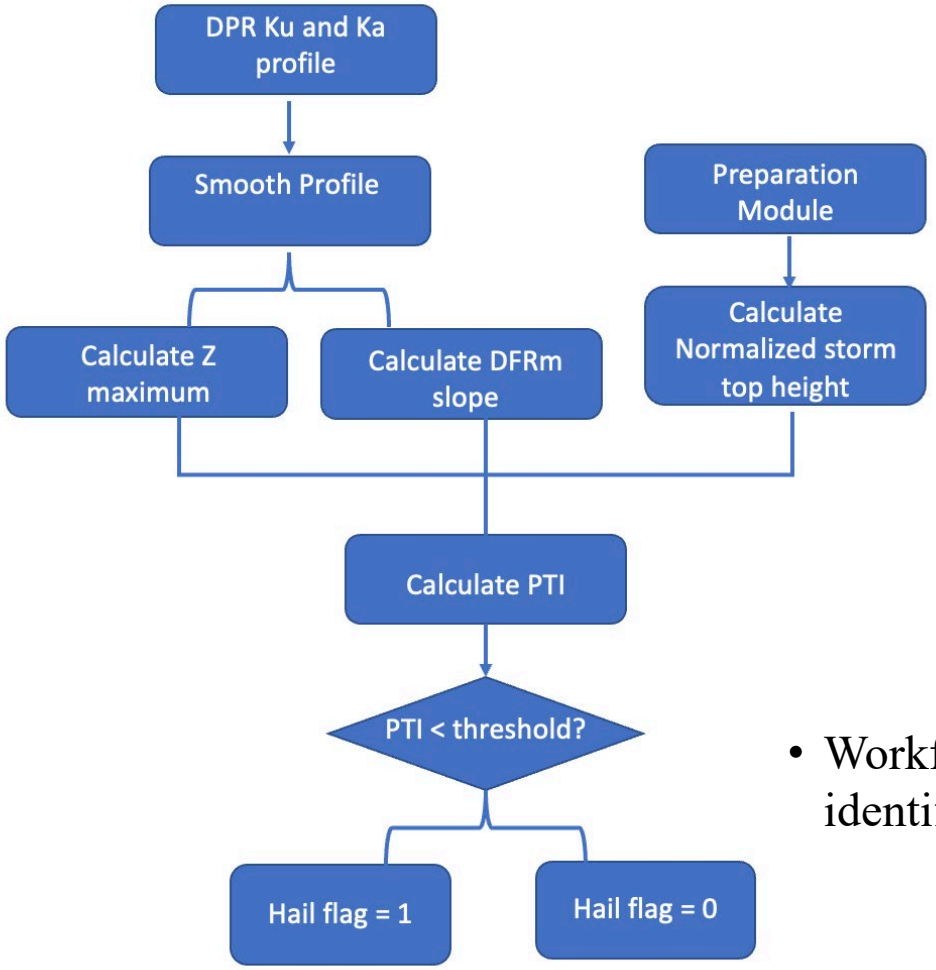
- GPM DPR Version 7 products from our team are evaluated on a global scale with multiple years.
- Performance of the algorithms after GPM boost is evaluated.
- New feature for GPM DPR level-2 Algorithm in V8 is discussed and sample validation cases illustrate promising results.

Thank you

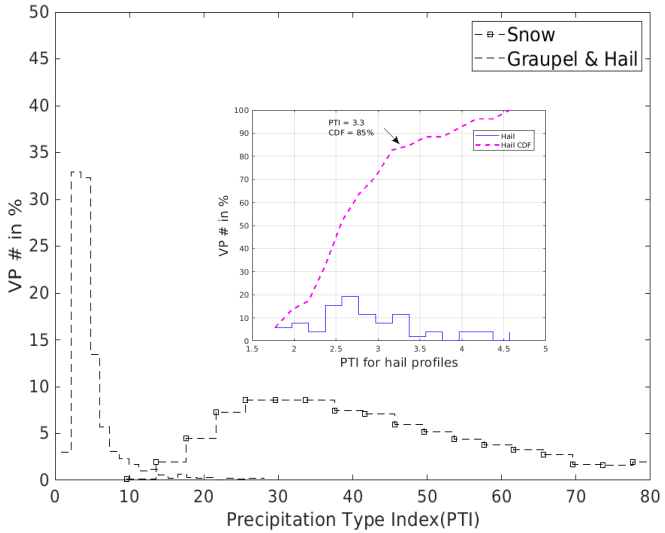
Hydrometeor classification on DPR Vertical Profile



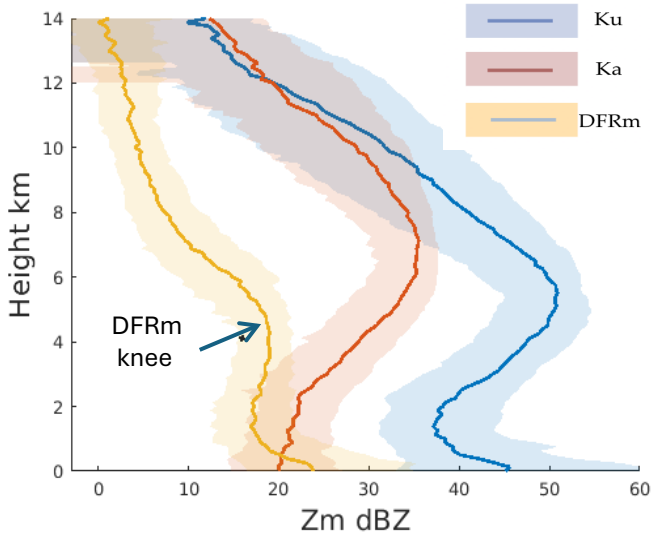
More activities on hail algorithm validation



- Workflow of the hail identification algorithm

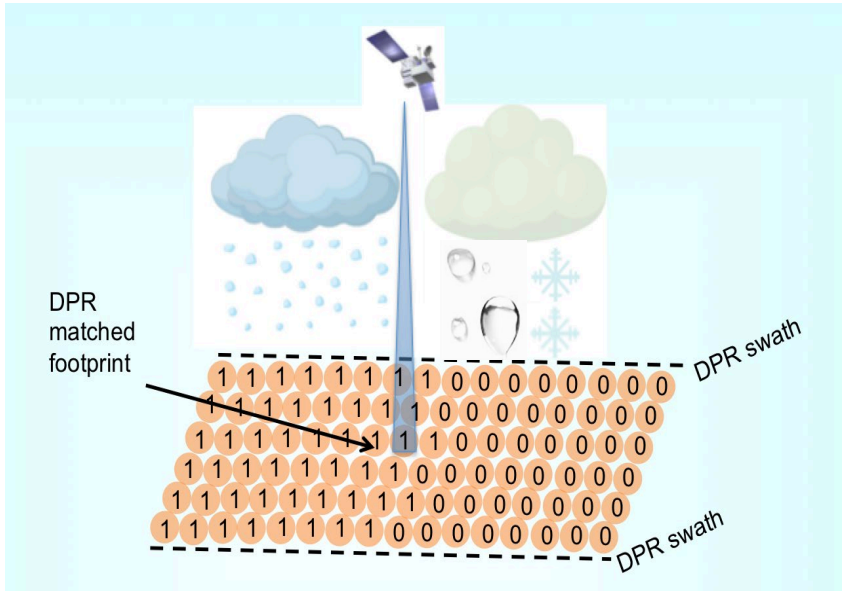


- Precipitation type index (PTI) is a good indicator of different hydrometeor types. Le and Chandrasekar (2017, 2020, 2021,2022)

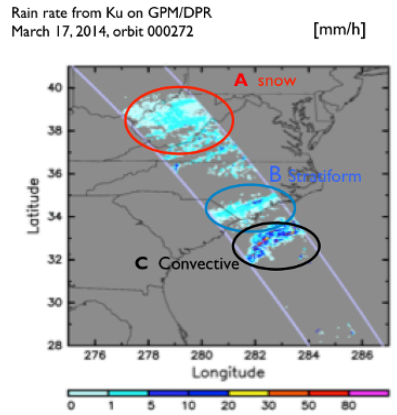


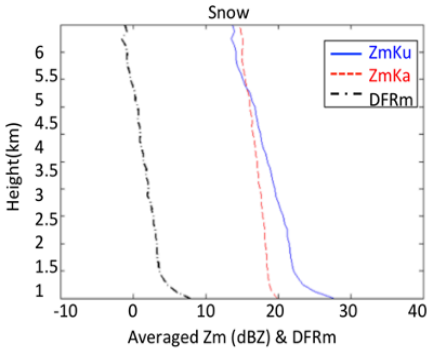
Evaluation of V7 Products

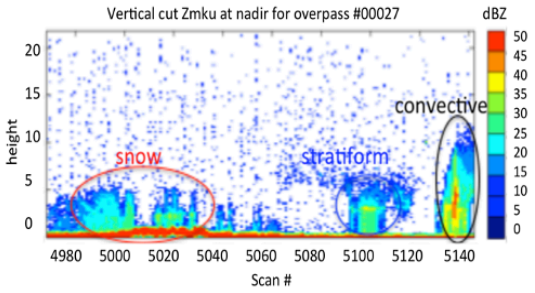
- Precipitation type index (PTI) is a good indicator of different hydrometeor types.

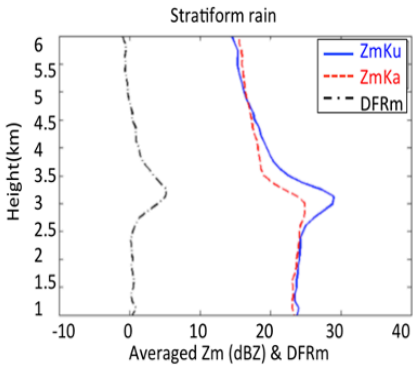


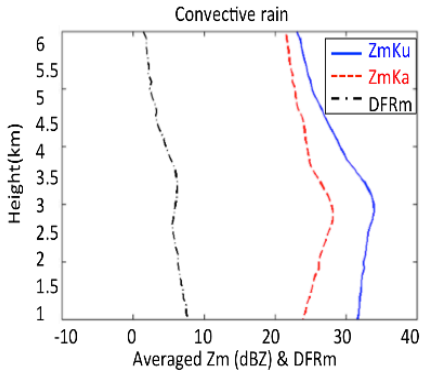
Details in Le and Chandrasekar (2017, 2020)

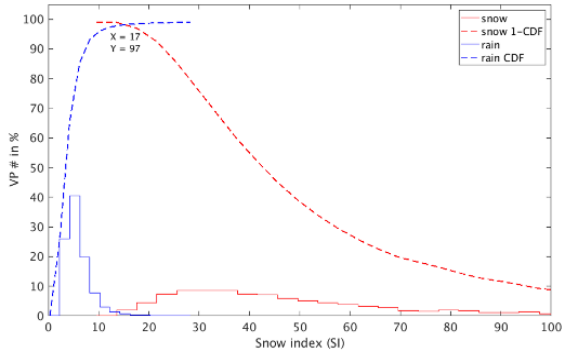












$$\textbf{\textit{Precipitation type index (PTI)}} = \frac{DFR_m \text{ slope with respect to height}}{\text{Maximum of } Zm_{ku} \quad X \quad \text{Storm top height}}$$

Magnitude of slope and normalized Zmku and storm top height are used in calculating PTI.