PRECIPITATION PROFILE ALGORITHM FOR GPM: IDENTIFICATION OF HAIL

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outline

• Background

• Algorithm Description

• Global Distribution of the Graupel / Hail

• Study of extreme cases during Relampago field campaign

• Summary
GPM satellite mission: 5 year of Global Precipitation Measurement

GPM Constellation

- Next generation joint Global Precipitation measurement (GPM) mission by NASA/JAXA.
- Follow up mission for TRMM (Tropical Rainfall Measurement Mission).
- Equipped with dual frequency precipitation radar (DPR) operating at Ku- and Ka-band.
- International collaboration mission including many countries.

The H-IIA F23 was launched with the GPM core observatory onboard at 3:37 a.m. on February 28, 2014 (Japan Standard Time, JST) from the Tanegashima Space Center. (http://jda.jaxa.jp/en/)
Background

GPM Core Observatory

- Launched on Feb 27th, 2014
- Coverage area 65°S – 65° N
- 3D precipitation observations around the globe every 93 minutes.

Image source: www.pmm.nasa.gov/category/pmm-resource-type/image

Stratiform

Convective

\[\text{DFR}_m = Z_{m_k} - Z_{m_a} = (Z_{e_k} - A_{e_k}) - (Z_{e_a} - A_{e_a})\]

\[\text{DFR}_m = Z_{m_k} - Z_{m_a} = (Z_{e_k} - Z_{e_a}) + (A_{e_a} - A_{e_k}) = \text{DFR}_m + \delta\text{PIA}\]
In the current DPR level-2 algorithm, the “flagSurfaceSnowfall” is a 0 or 1 product detects whether surface has snowfall or not.

Similar approach is applied to identify graupel and hail precipitation using a precipitation type index (PTI)

\[ \text{PTI} = \frac{\text{DFR}_m \text{ slope with respect to height}}{\text{Maximum of } Z_{m\text{ku}} \times \text{Storm top height}} \]

Magnitude of slope and normalized \(Z_{m\text{ku}}\) and storm top height are used in calculating PTI.
Background

The median profiles of the DFR observables complemented by the synthetic ground-based data for different hail fractions (Mroz et al. 2018).

The medium profile of DFR with hail. Different color represents different hail fraction.

DFR knee, signal of multiple scattering

Typical profile of DFR for stratiform rain with snow particles above freezing level (Le and Chandrasekar, 2013)

GH profile features:

- Large DFRm values can be observed associated with large rimed hail particles and large attenuation.
- The slope of the DFRm is smaller than aggregates. In hail formation, heavily rimed particles lifted up by the updraft several times, there is no strong indication of one-way size increase or attenuation difference increase.
- High storm top.

When multiple scattering happens, attenuation is driven by scattering more than absorption processes. The sloping of the Ka reflectivity profile is completely anomalous when compared to that of the Ku channel. The averaged extinction coefficient for Ka band is even smaller than Ku. This is the driver for the appearance of the DFRm knee.

DFRm = DFR + δPIA

Observed and modeled DFR profile with multiple scattering effect (Battaglia et al. 2015).
We collect DPR profiles with graupel and hail identified using NEXRAD radar network. Hydrometeor classification algorithm (DROPS) is applied to the NEXRAD radar data. We pick DPR vertical profiles closest to the location where DROPS detects graupel and hail. More than 1000 profiles are collected.

We study features of these dual-frequency profiles. They include maximum of Zmku along vertical profile, mean of absolute of DFRm slope, and storm top height. These three features are used in calculating the precipitation type index.

Storm top height in km is a GPM product in the preparation module defined as the location where precipitation echo is larger than a threshold.
Overlap between rain and Graupel & Hail histogram are convective rain (which believed have higher density particles aloft).

Statistically, around 85% of graupel/hail profiles have this index value smaller than 5.5 and 90% smaller than 6.0. This threshold can be used to identify profiles with graupel and hail.
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Algorithm flowchart

DPR Ku and Ka profiles

Smoothed Zmku & Zmka
(moving average of 5 bins along vertical profile)

Calculate Zmku maximum

Calculate DFRm slope

Storm top height

Preparation Module

Calculate PTI

PTI < threshold?

Yes

GH flag = 1 (graupel and hail exists)

No

GH flag = 0 (no graupel and hail)
In the current GPM DPR algorithm, there is a product called “flagHeavyIcePrecip”, which is a flag built based on thresholds of reflectivity and dual-frequency ratio (Iguchi, 2018).

Since profiles with graupel and hail are considered heavy ice precipitation. It is reasonable to perform to comparison between them.

We collected 22 heavy precipitation cases from year 2014 to 2018 compare each case side by side. For the ease of the comparison, we call the flag used in this method the “GH flag”, and the flag in the GPM product the “heavy flag”. Averaged matching percentage between GH flag and heavy flag is around 87%. (Le. and Chandrasekar, 2018)
Global Distribution of the Graupel / Hail

- The global distribution plot for Graupel/Hail flag is generated by counting the flag (Boolean product) for year 2018 and map the count to the 2° x 2° Lat / Lon box.

- The global distribution plot for Convective rain count in 2018.

- Percentage of Convective rain that is produced by graupel and hail in 2018.
Global Distribution of the Graupel / Hail

Winter:
December, January and February.

Summer:
June, July and August.

- Consistent with the findings shown in Iguchi et al. 2018, more GH profiles are found in tropical and subtropical regions.

- High percentage regions are in central Africa, South America, and Australia. These regions correspond well with active lightning regions where is believed to be associated with the existence of graupel at high altitudes.
Study of extreme cases during Relampago field campaign
RELAMPAGO is a collaborative project funded by NSF, NOAA, NASA, Servicio Meteorologico Nacional (SMN), Ministry of Education, Science and Technology of Argentina (MinCyT), Province of Cordoba, Brazil (INPE, CNPq, and FAPESP), and INVAP, S.E. to observe convective storms that produce high impact weather in the lee of the Andes mountains in Argentina. The Intensive Observing Period is between November 2018 to early January 2019.

RELAMPAGO provides unique observations of atmospheric and surface conditions in a region with substantial terrain and explore a regime of convection not observed comprehensively.
GPM overpass during Relampago

UTC time: 214823

CASE 1:
GPM overpass during Relampago

CASE 1:
GPM overpass during Relampago

CASE 1:

Vertical cut of Zmku and Zmka along the track at ray #34.

At ray # 34, scan of #1274 and #1275, the storm top height is as high as around 20 km.
Vertical profile at A and B

**A**
- Hail profile.
- Obvious DFRm knee.
- Suggest MS effect.
- Very high storm top.
- \(Z_{mkU}\) peak > 40dBZ above 0 degree.
  Suggest heavy precipitation as hail.

**B**
- Hail profile.
- Obvious DFRm knee.
- Suggest MS effect.
- Very high storm top.
- \(Z_{mkU}\) peak > 40dBZ above 0 degree.
  Suggest heavy precipitation as hail.
GPM overpass during Relampago

**CASE 1:**

Vertical cut of Zmku and Zmka along the track at ray #35.

At ray #35, scan #1274 and #1275, the storm top height is as high as around 20 km.
Vertical profile at C and D

C
- Typical Convective profile with high density particles as graupel.
- Large DFRm value suggests large particle size and large attenuation difference toward surface.
- No MS effect.
- Very high storm top.

D
- Profile has some hail contamination, or mixed with graupel.
- Has sign of DFRm knee but not very obvious.
- Very high storm top.
GPM overpass during Relampago

UTC time: 115303

**CASE 2:**

![Map of GPM orbit #26739 on date of 20181112]
GPM overpass during Relampago

CASE 2:
CASE 2:

Vertical cut of Zmku and Zmka along the track at ray #15, 16, 17. At location of A, B, C, D, E, F, we observe vertical profiles as high as 18~20 km.
Vertical profile at A and B

**A**
- Typical Convective profile with graupel.
- Melting region detected.
- No MS effect.
- Very high storm top.

**B**
- MLT detected.
- Very high storm top.
- Has sign of DFRm knee but not very obvious.
Vertical profile at C and D

C

- Typical Convective profile with high density particles as graupel.
- Melting region detected.
- No MS effect.
- Very high storm top.

D

- Hail profile.
- Obvious DFRm knee.
- Suggest MS effect.
- Very high storm top.
Vertical profile at E and F

**E**
- Typical Convective profile.
- Melting region detected.
- No MS effect.
- Very high storm top.

**F**
- Hail profile.
- Obvious DFRm knee.
- Suggest MS effect.
- Very high storm top.
Summary and Conclusion

- Algorithm to perform graupel and hail detection using DPR radar observation is described. The method uses precipitation type index with certain threshold to identify graupel and hail. The same index has been used on detecting surface snowfall. Case by case evaluation demonstrates good agreement with other GPM products such as the “flagHeavyIcePrecip”.

- The global distribution map of graupel and hail precipitation is generated. In addition, percentage of convective storm that produce graupel and hail is estimated. High percentage regions in the seasonal plots are central Africa, South America, and Australia. These regions correspond well with active lightning regions where is believed to be associated with the existence of graupel at high altitudes.

- Two extreme cases during Relampago field campaign are shown. The algorithm successfully identifies graupel and hail regions. Vertical profiles with very high storm top are discussed in details.
THANK YOU