PRECIPITATION TYPE AND PROFILE CLASSIFICATION

Module FOR GPM-DPR

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Outline

- Objective
- Introduction
- Profile classification method for GPM DPR L2 classification module

  ---- Precipitation type classification model (PCM)

  ---- Hydrometeor identification model (HIM)

- Conclusions

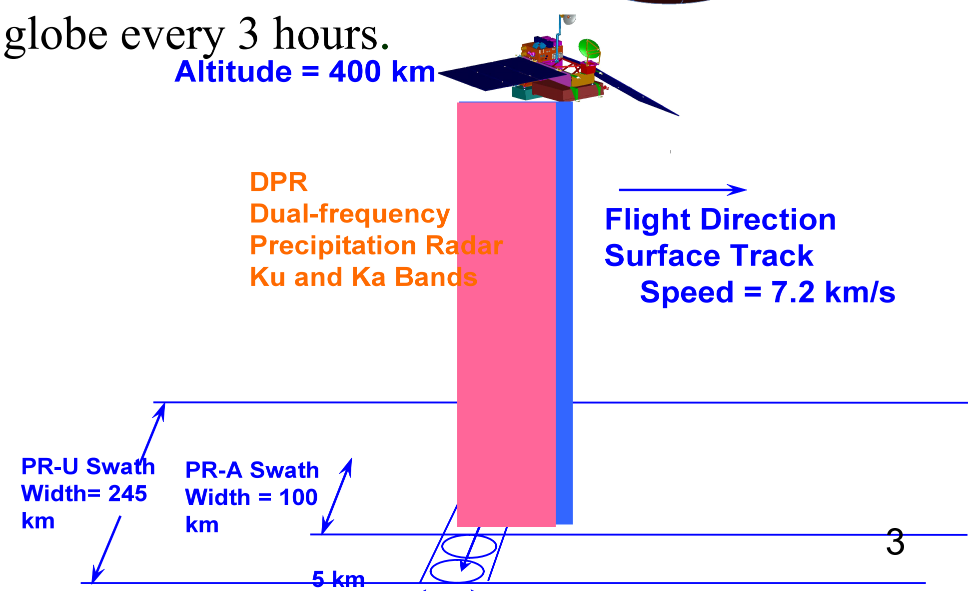
Introduction: Global Precipitation Observation

Incoming space precipitation radar-----GPM DPR (2013 ~) jointly by US and Japan.

Global Precipitation Measurement (GPM) Satellite

Dual-frequency Precipitation Radar (DPR)

- Ku-band (13.6 GHz) similar to TRMM-PR
- Ka-band (35.5 GHz) –0.87 cm. wavelength
- Coverage area 65°S – 65° N
- 3D precipitation observations around the globe every 3 hours.



Key benefits of GPM-DPR

• Retrieve more accurate DSD and thus improve accuracy of rainfall rate estimate.

$$R = \frac{\pi}{6}\int v(D)D^3N(D)dD$$

• Be able to discriminate between rain and frozen precipitation

Objective

<u>Classification module</u> is a critical module in the microphysical retrieval system for precipitation radar.

The nature of microphysical models and algorithms used in the retrievals are determined by the precipitation type for each profile.

Flowchart of GPM-DPR L2 algorithm

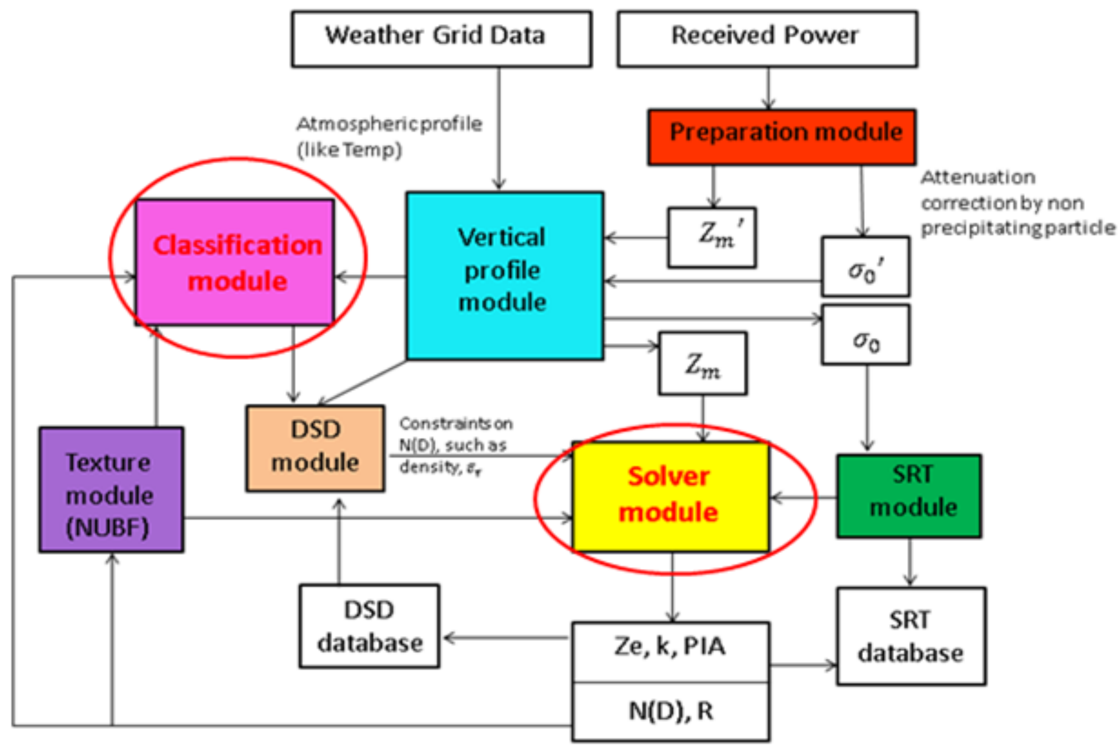
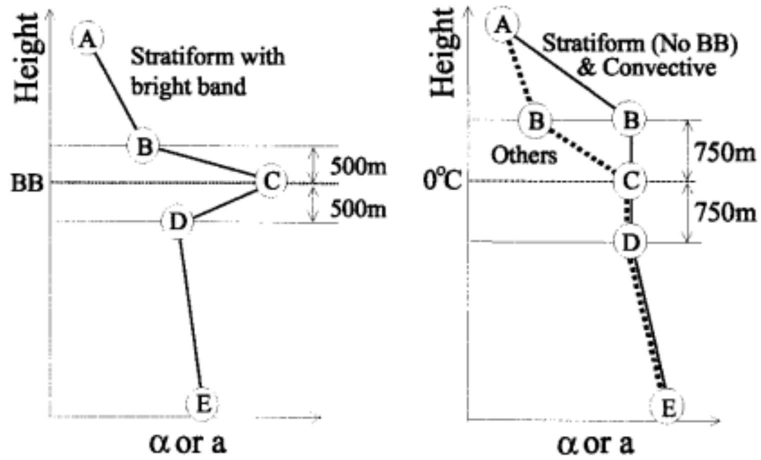


Figure courtesy JAXA

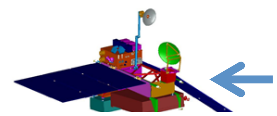
Background of DFRm

TRMM-PR

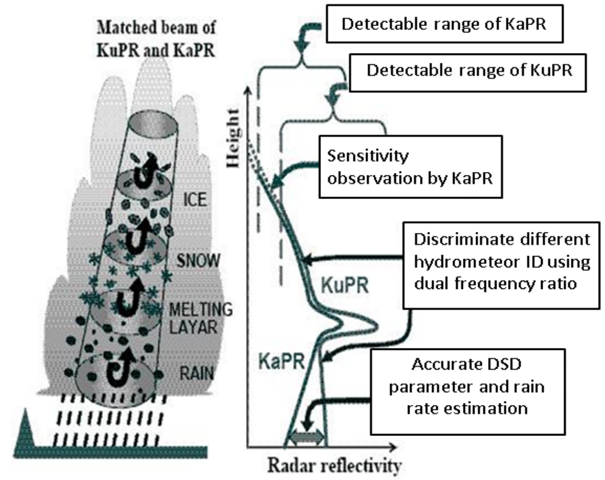


Iguchi et al. (2000)

GPM-DPR



Dual precipitation radar



Senbokuya et al. (2004)

Measured dual-frequency ratio (*DFRm*)

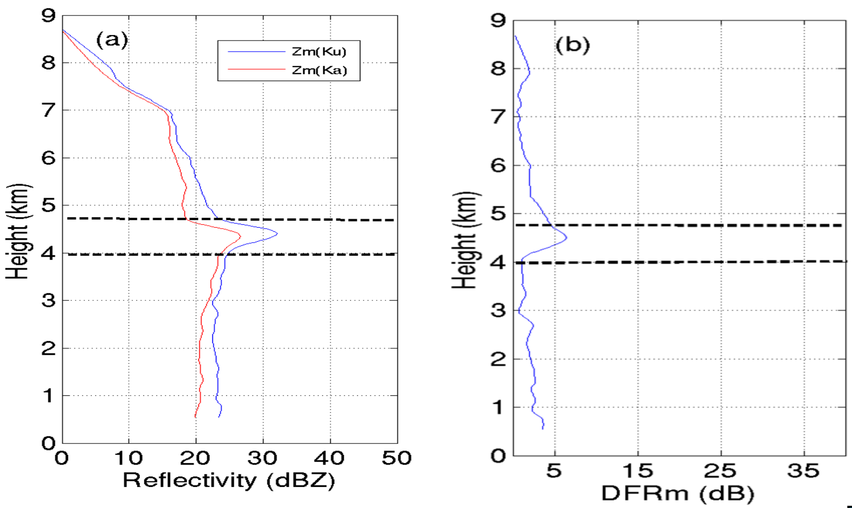
$$DFR_m = Z_m(K_u) - Z_m(K_a) = (Z_e(K_u) - PIA_{K_u}) - (Z_e(K_a) - PIA_{K_a})$$
$$= (Z_e(K_u) - Z_e(K_a)) + (PIA_{K_a} - PIA_{K_u}) = DFR + \delta PIA$$

DFR : Dual-frequency ratio. Caused by Non-Rayleigh scattering

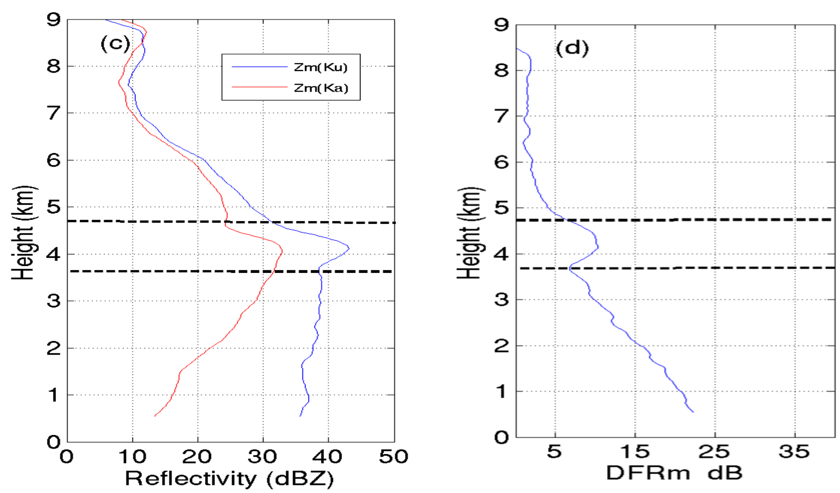
δPIA : Attenuation difference (>0 dB)

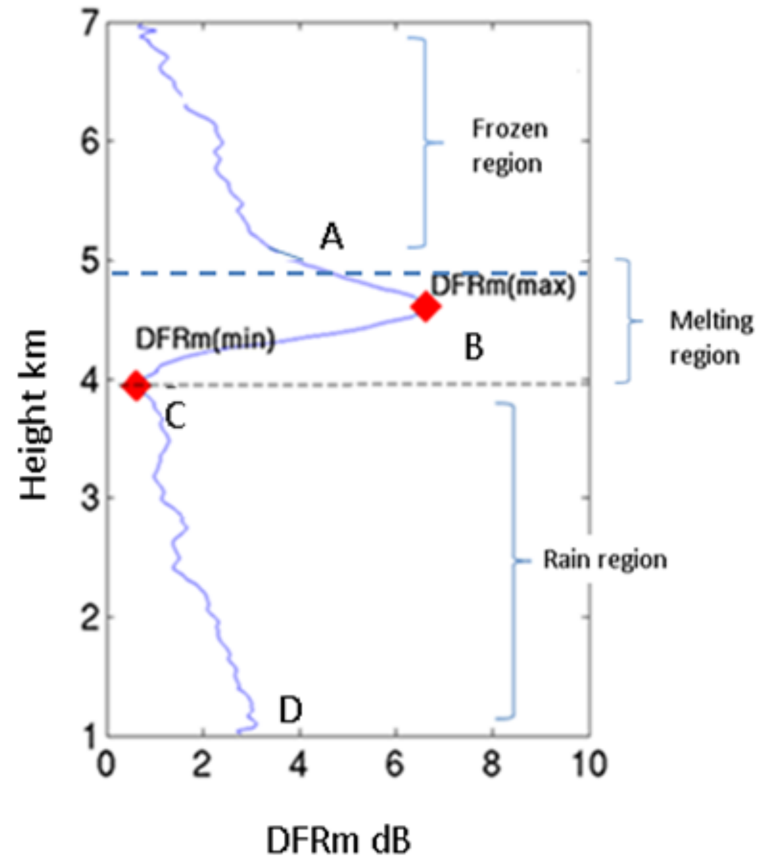
Background of DFRm

Stratiform rain



Convective rain

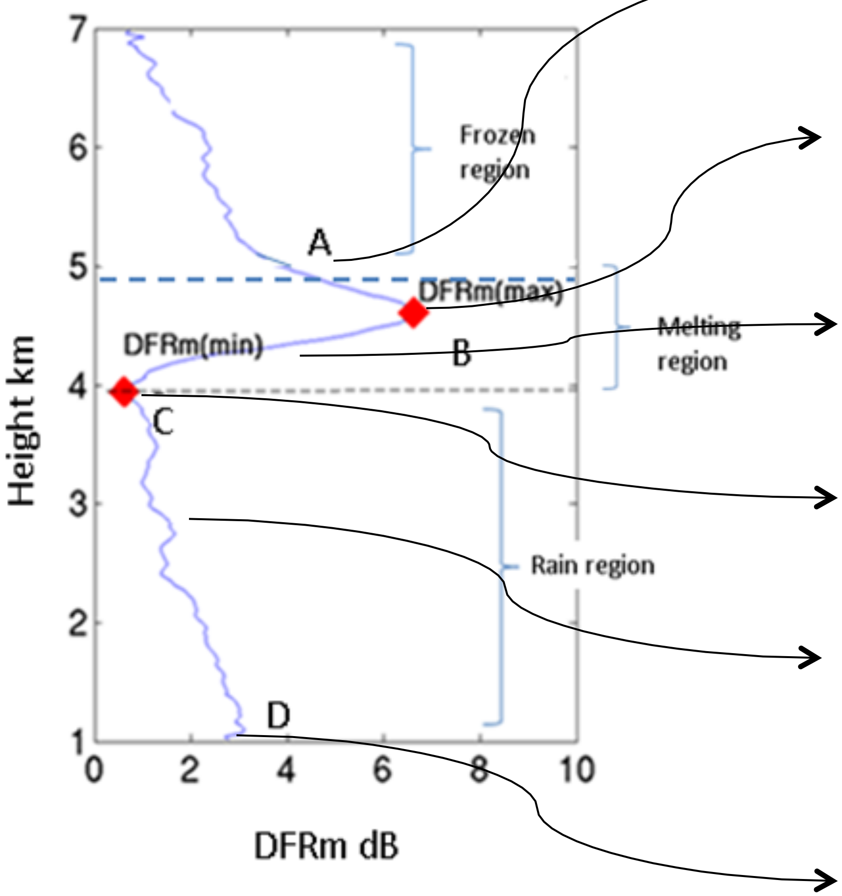




Dashed lines are melting layer boundaries using criteria in Le. et al (2011)

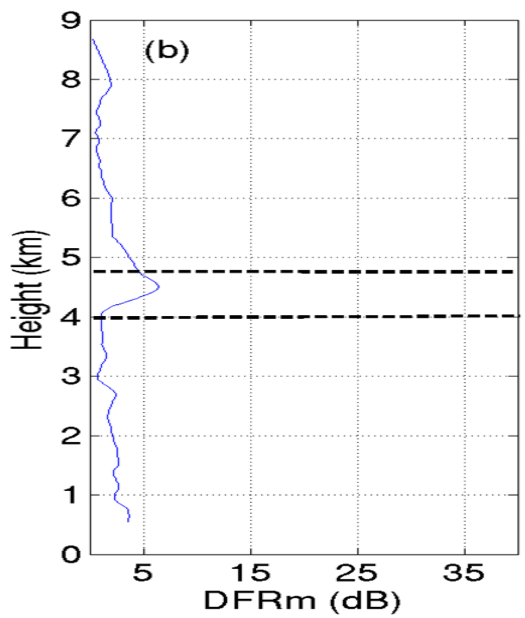
Background of DFRm

Key characteristics of DFRm profile

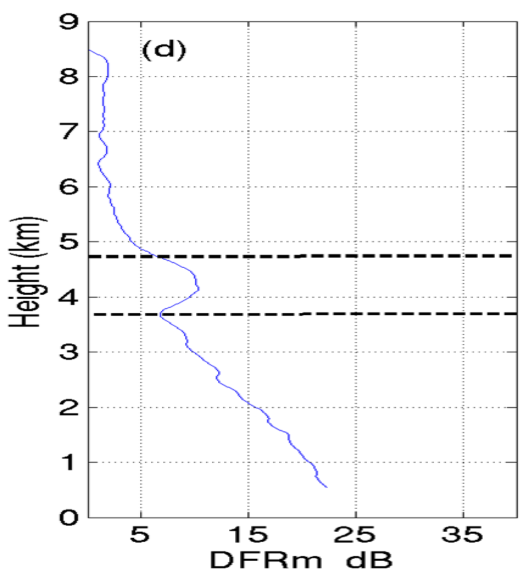


- DFRm slope maximum value at A
- DFRm maximum value at B
- DFRm slope between maximum and local minimum value (B,C slope)
- DFRm local minimum value at C
- DFRm slope between local minimum value and near surface value (C, D slope)
- DFRm value near surface at D

Background of DFRm



Stratiform rain



Convective rain

1. DFRm max value is larger for convective rain than stratiform rain.
2. Slope of DFRm between max and min value is larger for stratiform rain than convective rain.
3. DFRm local min value is larger for convective rain than stratiform rain.
4. Slope of DFRm between local min and near surface value is larger for convective rain than stratiform rain.
5. DFRm value at near surface is much larger for convective rain than stratiform rain.

Profile classification method

- Profile type classification model (PCM)

  ----- To classify stratiform, convective , and other rain type.

- Hydrometeor Identification model (HIM)

  ----- To detect melting layer boundaries (where melting starts and ends)

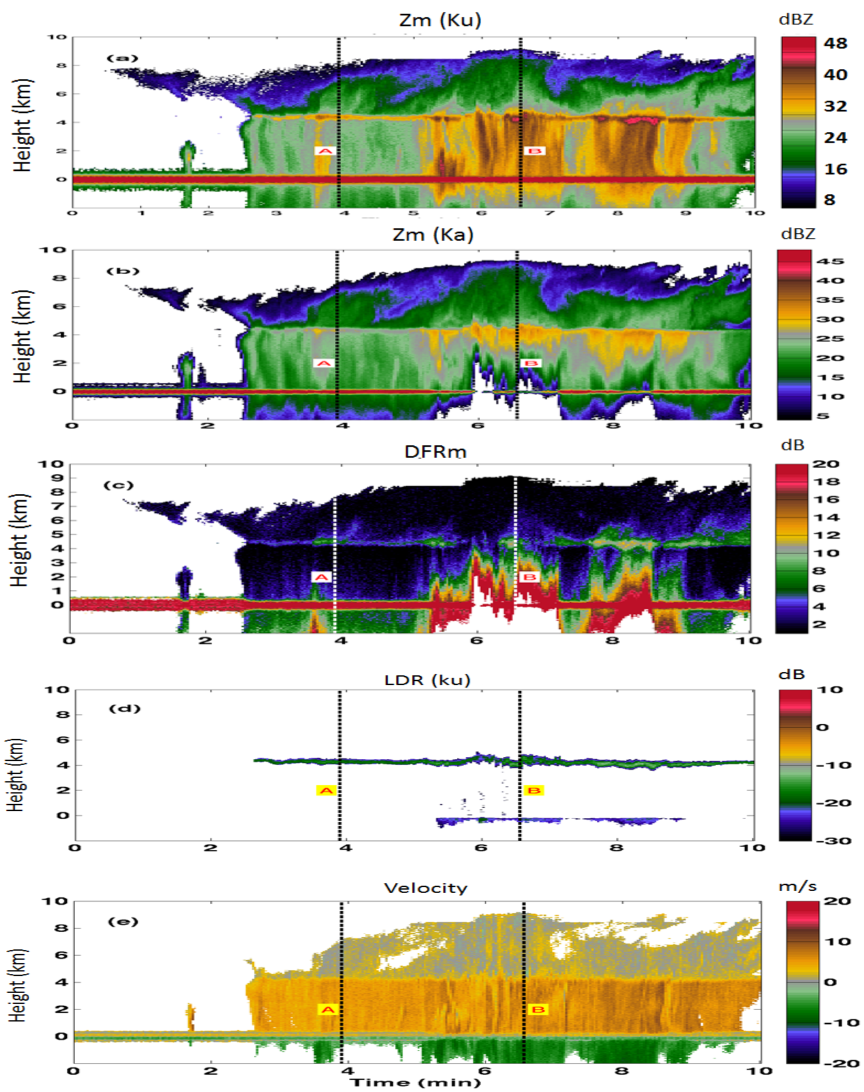
- Both PCM and HIM models are developed based on *DFRm* profile and its range variability.

- High resolution APR2 radar data is used for demonstration the principles.

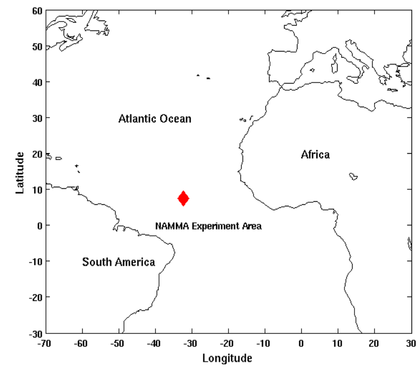
  ---- Emulate what DPR will observe.
  ---- Fine vertical resolution (~30m) keeps detailed information in melting layer.

Study of characteristics of DFRm using Airborne Precipitation radar (APR2) observation

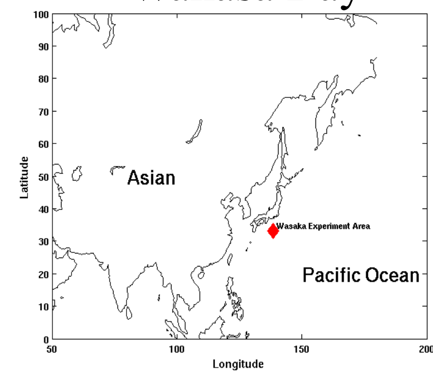
NAMMA 2006-0903-142134



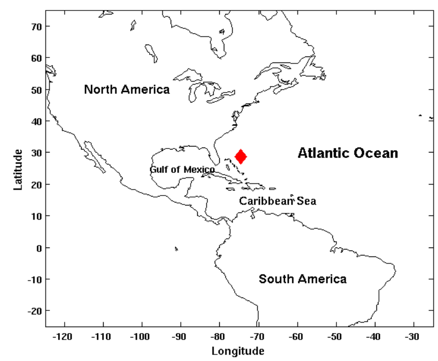
NAMMA

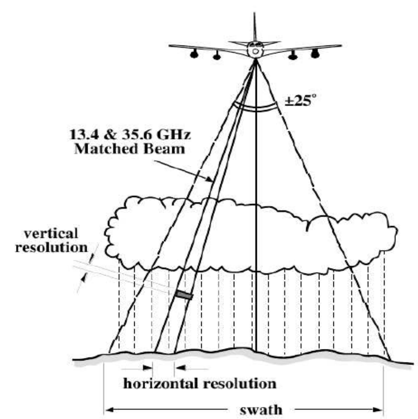


Wakasa Bay



GRIP





2nd generation Airborne Precipitation Radar (APR-2) by NASA/JPL

- 2 Channels: 13.6 GHz
  35.6 GHz

Profile classification method----PCM

The signature of DFRm can be featured by DFRm max and min value as well as its slope. In order to quantify these features, a set of DFRm indices are defined.

Let

$$V1 = \frac{DFR_m(max) - DFR_m(min)}{DFR_m(max) + DFR_m(min)} \quad (1)$$

Let V2 be the absolute value of mean slope below the local minimum point.

$$\text{V2=abs(mean(}DFR_m\ slope) \quad (2)$$

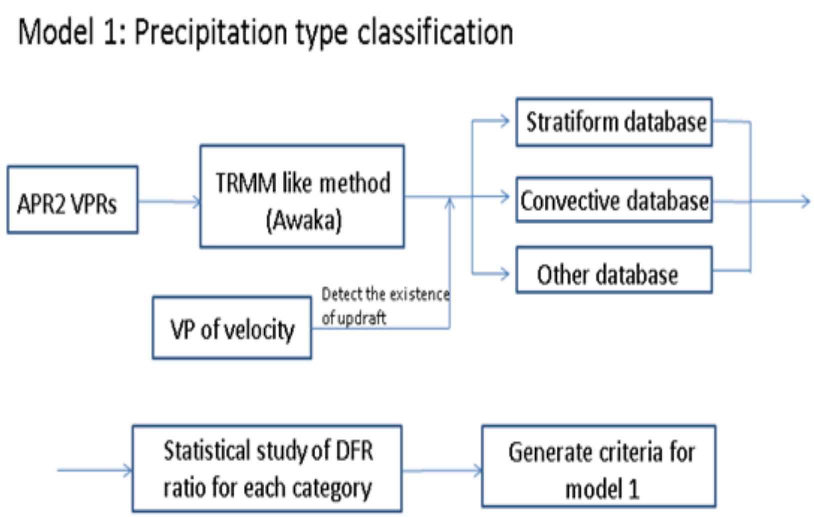
Both V1 and V2 values are normalized values and not dependent on depth or height of melting layer. In order to further enlarge the difference, a third DFRm index is defined as

$$\text{V3=}\frac{V1}{V2} \quad (3)$$

Index V3 can be an effective parameter and has separable threshold to perform classification

Profile classification method------PCM

- In order to validate the precipitation classification schematic, the airborne precipitation radar (APR2) data during NAMMA and GRIP experiment are used.
- Both TRMM-like method (Awaka et al. 1997) and the Doppler velocity information which is available for APR2 data are combined to generate the stratiform, convective and other rain type



Figure, Flow chart of *PCM* analysis

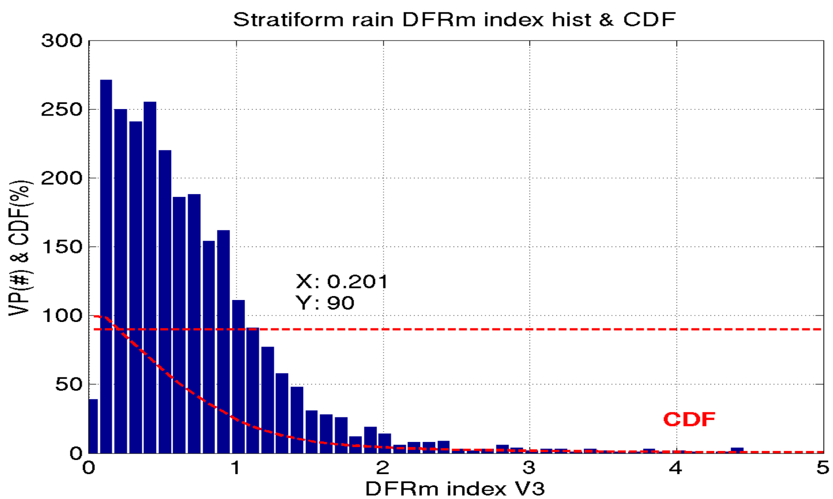
TRMM-like	Velocity	decision
‘S’	‘U’	‘C’
‘C’	‘U’	‘C’
‘O’	‘U’	‘C’
‘S’	‘no’	‘S’
‘C’	‘no’	‘C’
‘O’	‘no’	‘O’

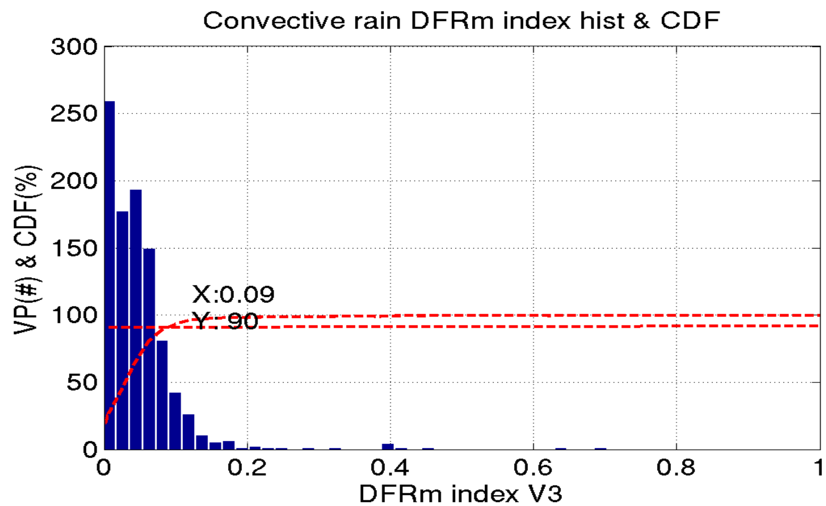
Figure Combined decision from TRMM-like method and velocity information. ‘S’,‘C’,’O’ represent stratiform, convective and other rain type. ‘U’ and ‘no’ represent whether updraft exists or not respectively.

Profile classification method------PCM

NAMMA (NASA African Monsoon Multidisciplinary Analysis) experiment data

Histogram of DFRm index V3





The CDF or (1-CDF)(cumulative density function) of V3 is calculated and the 90% confidence line gives:

Convective rain: V3< C1

Stratiform rain: V3>C2

90% CDF	Based on NAMMA APR2 data
C1	0.09
C2	0.201

Profile classification method------PCM

90 % CDF	NAMMA	GRIP	Wakasa Bay
C1	0.09	0.120	0.101
C2	0.201	0.216	0.192

- In NAMMA, GRIP and Wakasa Bay cases, 90% CDF confidence line show that stratiform and convective rain can be separated by DFRm index V3.

- C2 value (90% CDF value for Stratiform rain) for NAMMA, GRIP and Wakasa Bay cases are very close. This a good sign that C2 value might be stable at different geometry locations.

- C1 value (90% CDF value for Convective rain) shows some slight variation

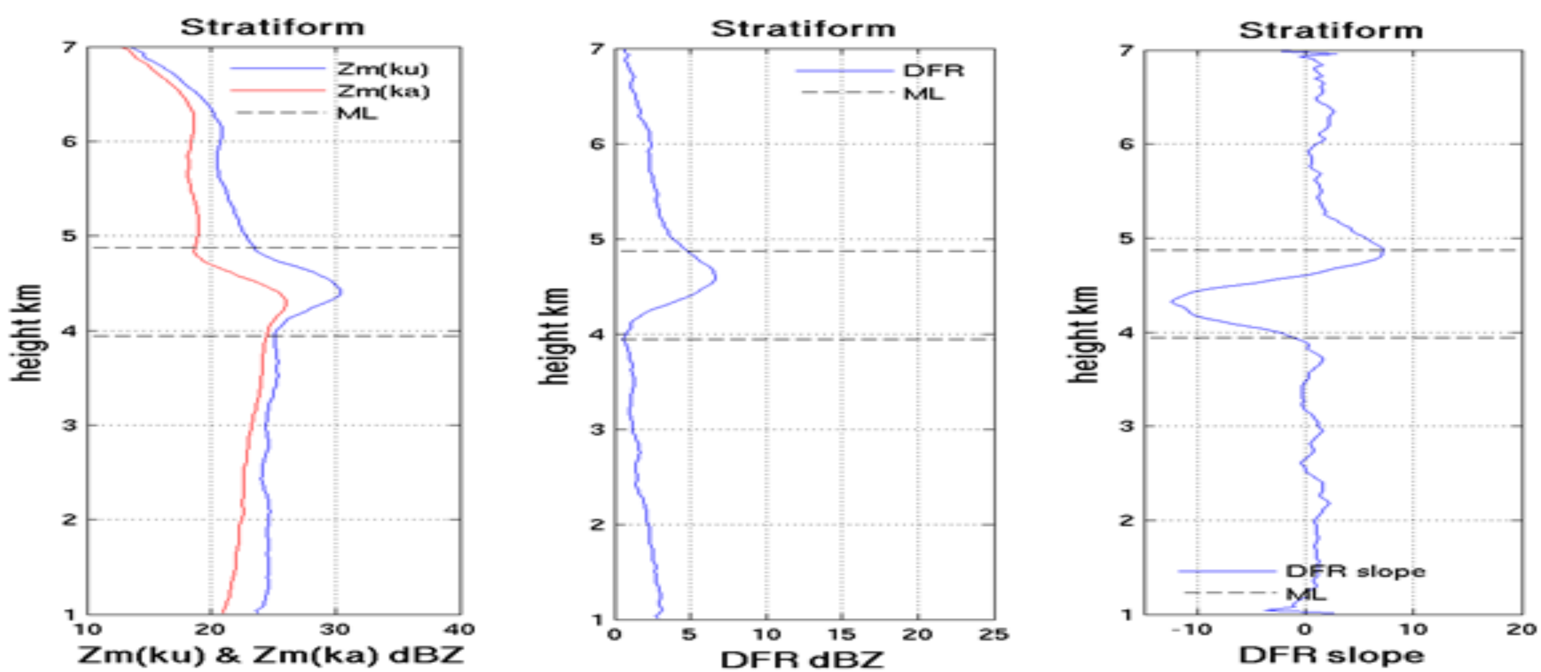
Profile classification method------HIM

- Hydrometeor identification model *(HIM)* is the second model of the profile classification method.
- As discussed before, *DFRm* is useful parameter to detect the hydrometer phase transition.

The main parameter used in *HIM* is *DFRm* and its range variability.

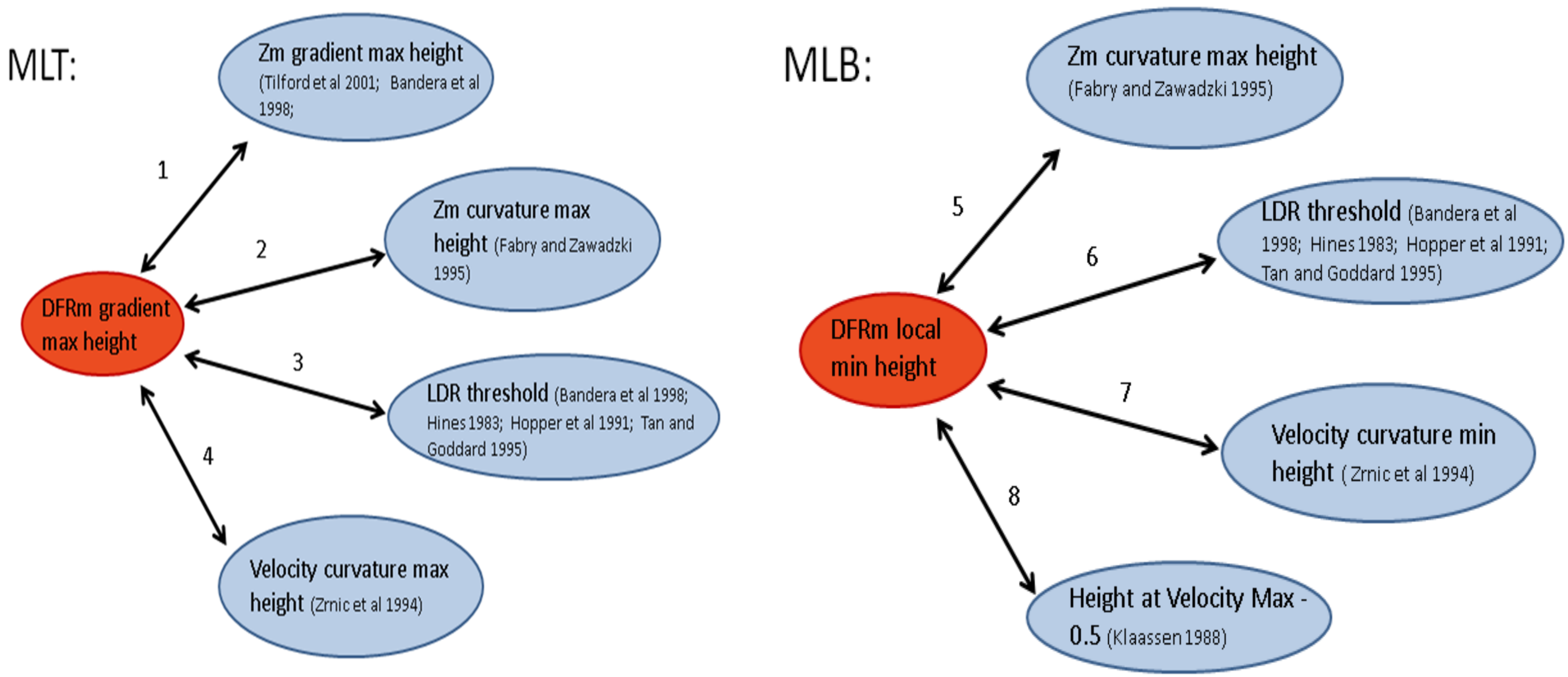
---- Melting layer top is the height at which *DFRm* gradient has maximum value.

----Melting layer bottom is the height at which *DFRm* has a local minimum value.



Profile classification method------HIM

For validation purpose, DFRm criteria used in HIM is compared to other existing criteria shown in the figure.

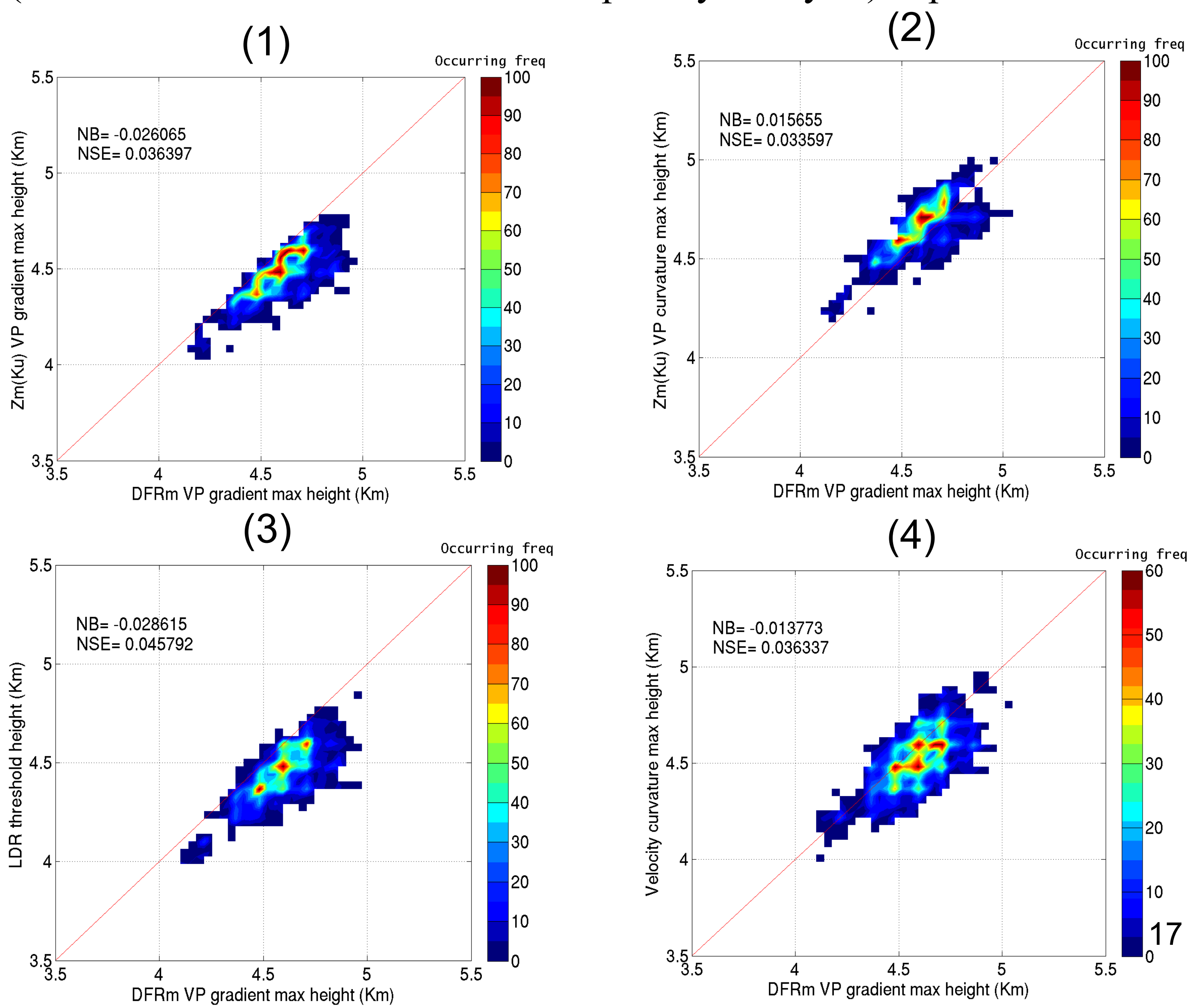


Figure, Schematic plot of some well known criteria for melting layer boundaries detection and their possible relations with *DFRm* criteria used in *HIM*.

Profile classification method------HIM

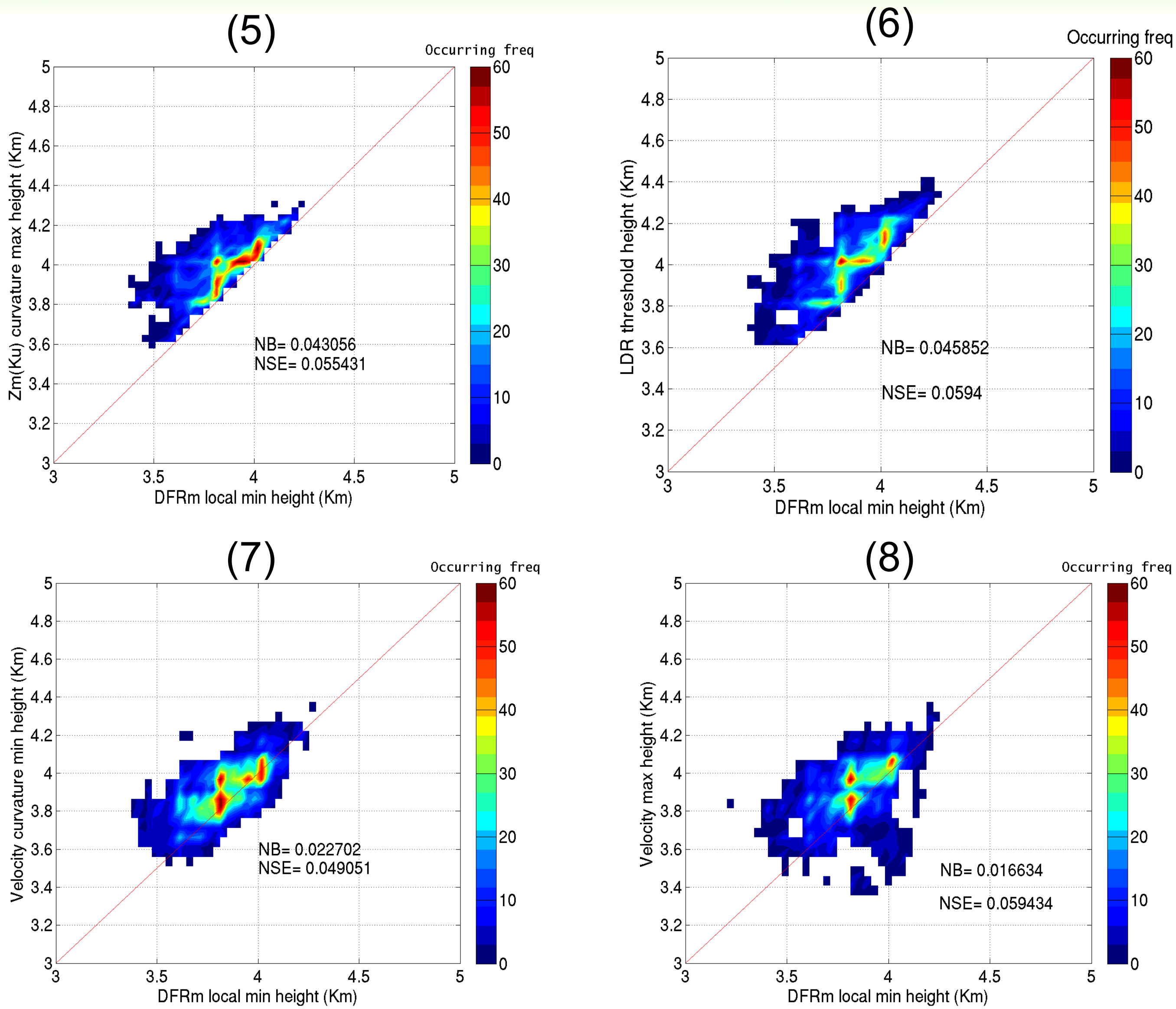
NAMMA (NASA African Monsoon Multidisciplinary Analysis) experiment data

For melting layer top comparisons:



Profile classification method------HIM

For melting layer bottom comparisons:



Profile classification method------HIM

	Criteria	DFRm slope max (NAMMA)	DFRm slope max (GRIP)	DFRm slope max (Wakasa Bay)
Melting layer top comparisons	Zm slope max	NB= -0.026; NSE=0.036;	NB= -0.025; NSE=0.036;	NB= -0.049; NSE=0.066;
	Zm curvature max	NB= 0.016; NSE=0.033;	NB= 0.015; NSE=0.030;	NB= 0.028; NSE=0.052;
	LDR	NB= -0.028; NSE=0.045;	NB= -0.033; NSE=0.042;	NB= -0.06; NSE=0.072;
	* Velocity curvature max	NB= -0.013; NSE=0.036;	NB= -0.014; NSE=0.037;	NB= -0.019; NSE=0.056;
		DFRm local min (NAMMA)	DFRm local min (GRIP)	DFRm local min (Wakasa Bay)
Melting layer bottom comparisons	Zm curvature max	NB= 0.043; NSE= 0.055;	NB= 0.037; NSE=0.050;	NB= 0.043; NSE=0.069;
	LDR	NB= 0.045; NSE= 0.059;	NB= 0.040; NSE=0.054;	NB= 0.054; NSE=0.112;
	*Velocity curvature min	NB= 0.022; NSE= 0.049;	NB= 0.017; NSE=0.044;	NB= -0.0008; NSE=0.07;
	*Velocity max	NB= 0.016; NSE= 0.059;	NB= 0.019; NSE=0.043;	NB= -0.026; NSE=0.139;

Profile classification method------HIM

- Comparisons of melting layer boundaries for stratiform profile classified by PCM show similar trend for NAMMA, GRIP and Wakasa Bay experiments..

- *DFRm* criteria matches best with velocity criteria for both melting layer top and bottom comparisons for three experiments. Velocity profile is not available for GPM-DPR, but it reflects the true signatures of microphysics properties.

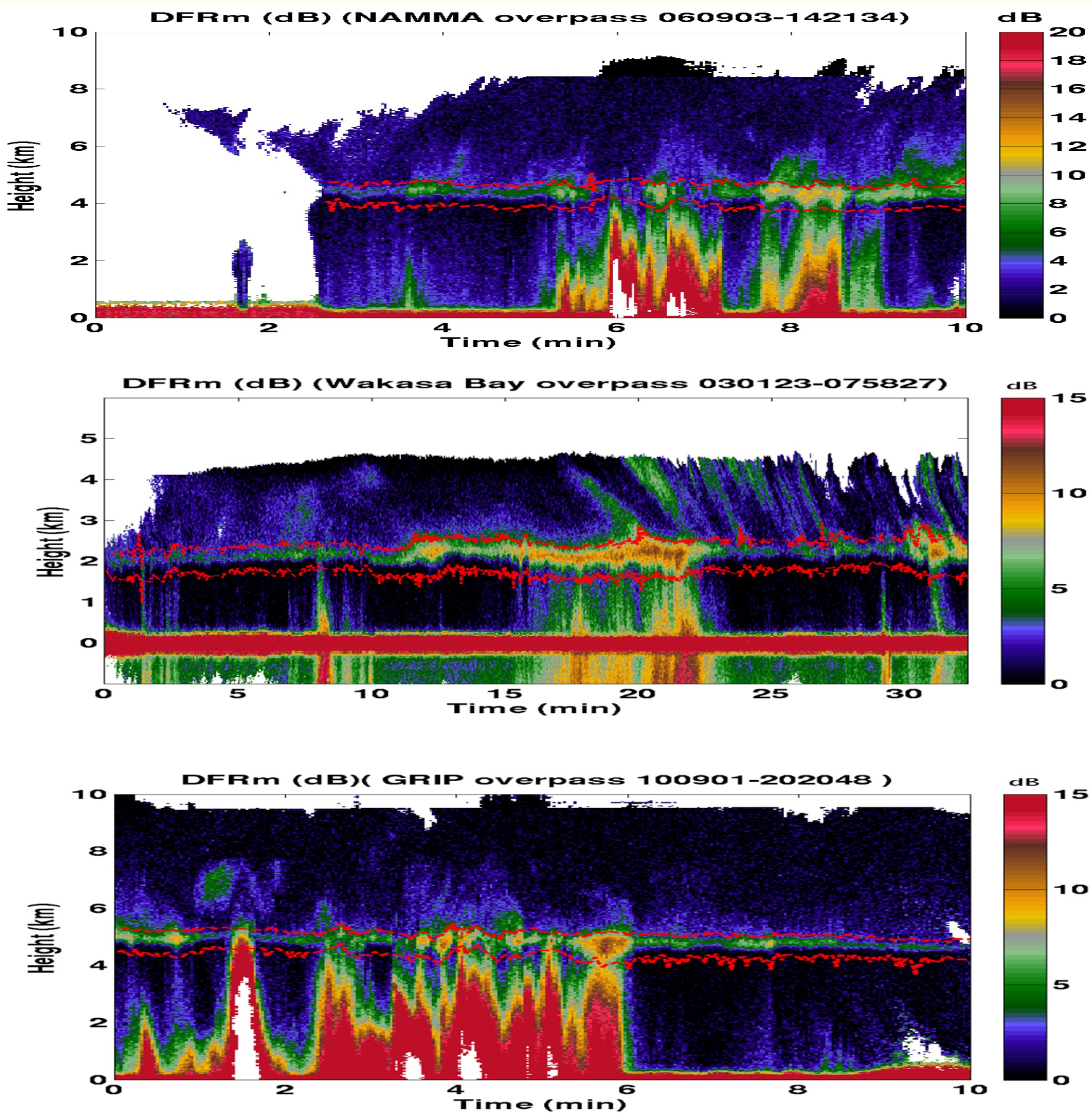
- LDR with threshold of -28 dB shows a narrower melting layer width than *DFRm* detector and this might be caused by the hard threshold or the relative poor data quality.

Profile classification method------HIM

- Although the comparisons shown above are based on stratiform rain profiles classified by *PCM*. *DFRm* criteria used in *HIM* **can be applied to profiles beyond stratiform rain**
- Table below shows the estimates between DFRm and LDR as well as velocity criteria based on all DFRm profiles with detectable bump (DFRm (max)-DFRm(min)>1 dB). Except for relative larger normalized standard error (NSE), NB values are very close to those shown for stratiform rain.
- For NAMMA data, around 77.5% of convective and other rain type profiles classified by *PCM* have detectable bump. The number for GRIP is 73.33%. The number of Wakasa bay is 88%. This makes the *HIM* criteria relatively independent of the *PCM* decision.

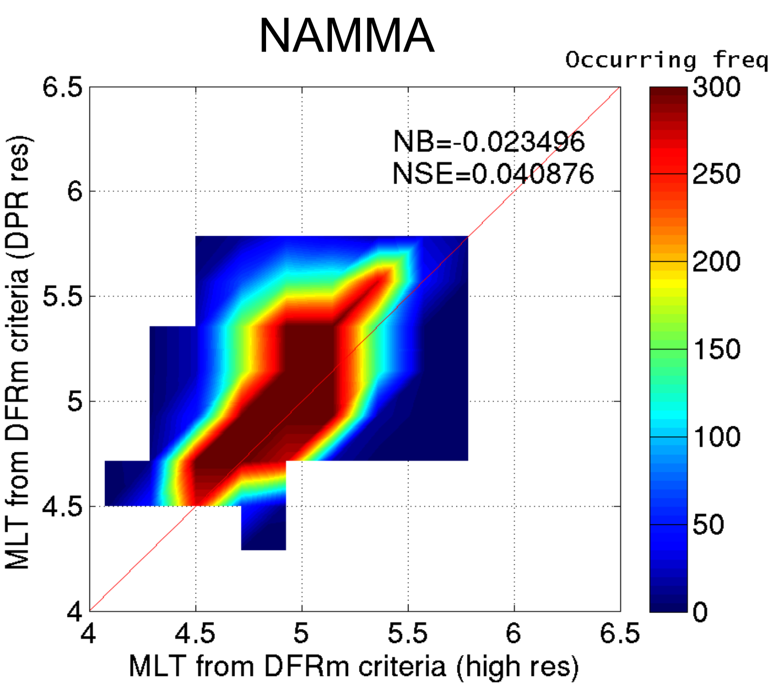
	DFRm criteria (NAMMA)	DFRm criteria (GRIP)	DFRm criteria (Wakasa Bay)
LDR	MLT: NB= - 0.021; NSE= 0.056; MLB: NB= 0.031; NSE=0.057;	MLT: NB= -0.029; NSE=0.045; MLB: NB= 0.029; NSE= 0.056;	MLT: NB= -0.049; NSE=0.098; MLB: NB=0.069; NSE=0.195;
Velocity curvature	MLT: NB= - 0.012; NSE=0.043; MLB: NB= 0.019; NSE=0.056;	MLT: NB= -0.014; NSE= 0.043; MLB: NB= 0.015; NSE= 0.052;	MLT: NB= -0.016; NSE=0.095; MLB: NB=-0.005; NSE=0.13;
Velocity max	MLB: NB= 0.01; NSE=0.064;	MLB: NB= 0.015; NSE=0.060;	MLB: NB=-0.036; NSE=0.164;

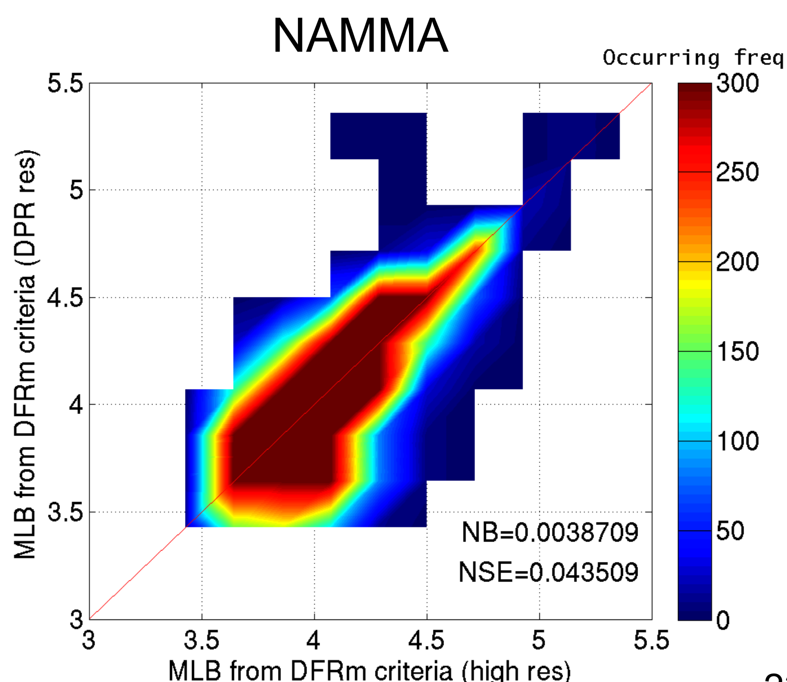
Profile classification method------overpass



Profile classification method------resolution degraded comparison

90% CDF	NAMMA (original)	GRIP (original)	NAMMA (resample)	GRIP (resample)
C1	0.09	0.12	0.093	0.13
C2	0.201	0.216	0.210	0.20





Summary

- DFRm precipitation type and profile classification module is presented for GPM.
- A set of indices are defined and subsequently used to perform profile classification. DFRm index V3 can be used to separate stratiform and convective rain.
- Cross validation of the classification algorithm was performed using auxiliary information such as velocity and linear depolarization ratio.
- For melting layer top and bottom comparison, *DFRm* criteria show the best match with velocity based decision.
- The evaluation of the resampled APR2 data (DPR resolution) shows the method is applicable to GPM-DPR observations.

Thank you