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Three-dimensional classification of precipitation particle types using GPM/DPR

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Introduction

GPM/DPR is expected to provide microphysical properties of hydrometeors, such as particle size distribution parameters (mass-weighted mean diameter, liquid/ice water content). The differential frequency ratio (DFR) can eliminate the effect of number concentration and provide information on particle size. According to Liao and Meneghini (2011), DFRs are expected to be larger in ice precipitation regions than in rainfall regions because ice precipitation particles are generally larger than raindrops.

In this study, we further subdivide ice precipitation particles into “aggregated particles (snowflakes)” and “rimed particles (graupel/hail)” to investigate whether it is possible to identify them. This capability is useful for improving the accuracy of retrieving properties of and for providing insight into the growth of ice precipitation particles.

❑ Objectives

To explore the capability of the GPM/DPR for separation of aggregated and rimed particles.

Radar simulations

In this study, we simulate the effective radar reflectivity factor of the Ku and Ka bands for aggregated particles and rimed particles to examine their classification ability.

❑ Effective radar reflectivity factor

$$Z_e = \frac{\lambda^4}{\pi^5 |K_w(\lambda)|^2} \int_0^\infty \sigma_b(D_{ice}, \rho_{ice}, \lambda)\, N(D_{eq}) dD_{eq}$$

where D_{ice} (mm) is maximum dimension of the ice particle, and D_{eq} (mm) is the melted diameter of ice particle. $|K_w(\lambda)|^2$ is 0.9255 and 0.8989 for Ku and Ka-band, respectively. σ_b is backscattering cross section and is computed using the spheroidal model with the T-matrix method. The effective dielectric constants are computed using the Bruggeman (1935) mixing equation.

❑ Mass−diameter (m−D) relationship

In this study, the difference in the m−D relationship between aggregated particles and rimed particles is used to distinguish between them.

$$m(D_{ice}) = a_m D_{ice}^{b_m}$$

where $a_m = 2.10 \times 10^{-5}$ and $b_m = 2.5$ for aggregated particles (Magono and Nakamura 1965) and $a_m = 1.70 \times 10^{-4.1}$ and $b_m = 3.1$ for rimed particles (Heymsfield and Kajikawa 1989).

❑ Particle size distribution (PSD) model

We assumed a normalized gamma PSD:

$$N(D_{eq}) = N_w f(\mu) \left(\frac{D_{eq}}{D_m}\right)^{\mu} \exp\left(-(4+\mu)\frac{D_{eq}}{D_m}\right)$$

$$D_{eq} = \left(\frac{6 a_m}{\pi \rho_w}\right)^{\frac{1}{3}} D_{ice}^{\frac{b_m}{3}}, \qquad \mathrm{N_w} = \frac{4^4}{\pi \rho_w} \frac{LWC}{D_m^4}$$

where D_m (mm) is mass-weighted mean diameter, μ is shape parameter and is fixed to 3 in this study, N_w (mm^{-1} m^{-3}) is intercept parameter which is function of D_m and liquid water content (LWC). The melted diameter D_{eq} is calculated from the m−D relationship, assuming a spherical shape.

❑ Simulation results

Figure 1 shows the simulated the effective radar reflectivity in the $Z_e(Ku) - DFR(= Z_e(Ku)/Z_e(Ka))$ plane for aggregated and rimed particles. $Z_e(Ku)$ becomes much larger for rimed particles than for aggregated particles for a given value of DFR. This means that the water content required to achieve the same size is greater for rimed particles than for aggregated particles, as the DFR increases with size of ice particles before melting. This relationship holds for a variety of PSD parameters (D_m, LWC).

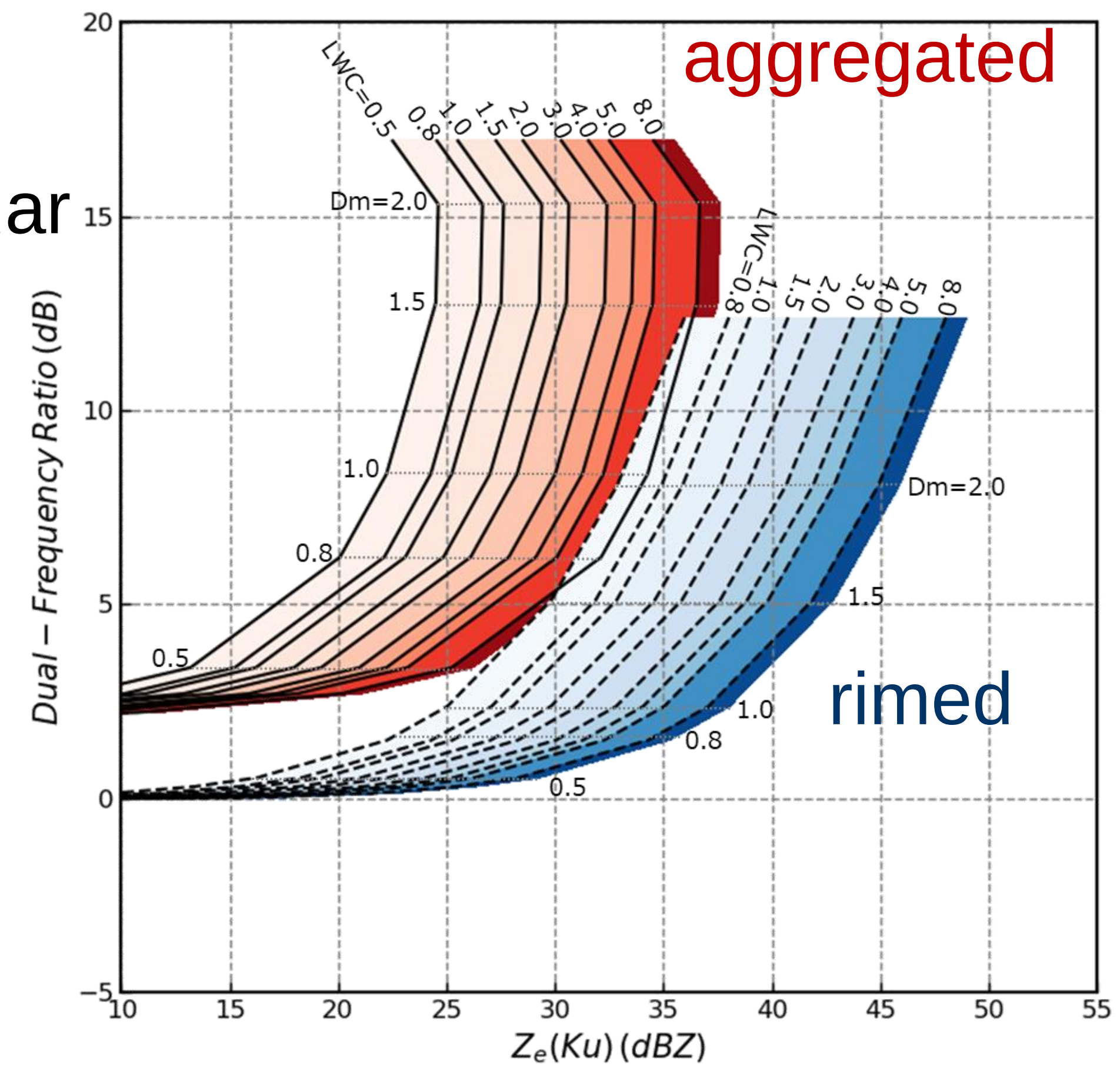

Fig. 1 $Z_e(Ku) - DFR$ relationship

Validation

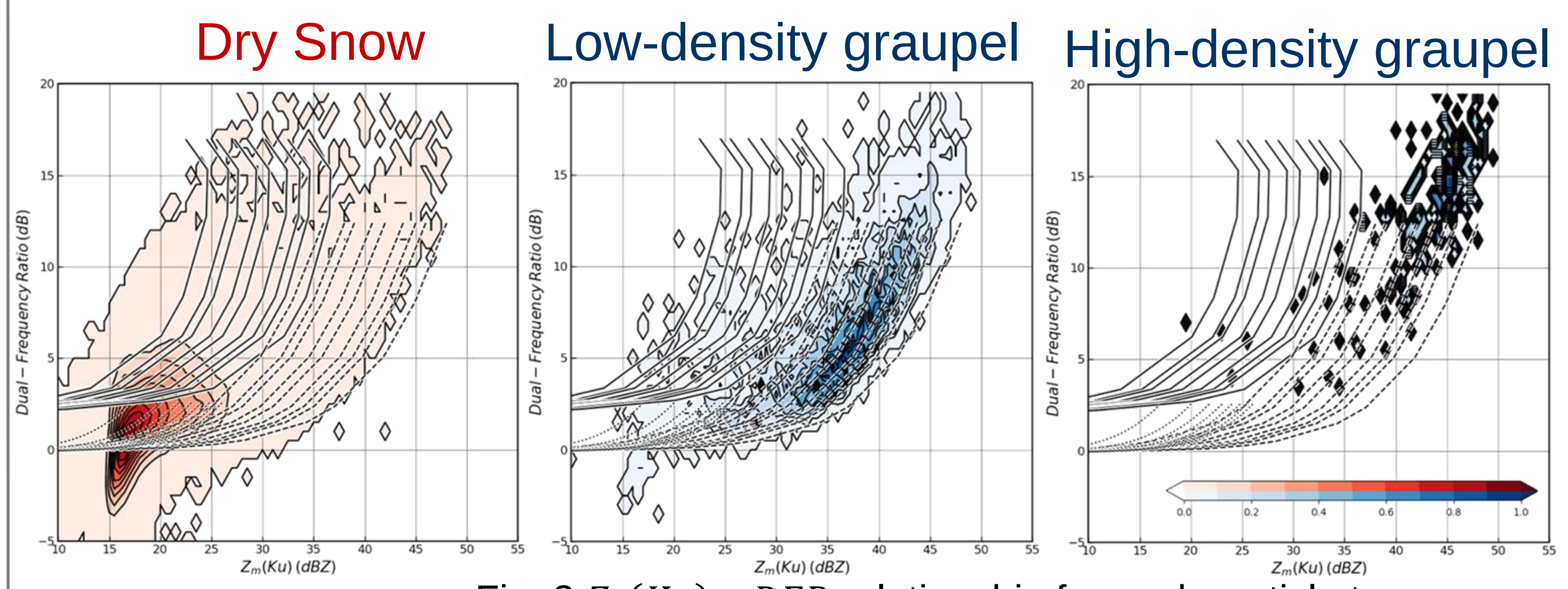

Fig. 2 $Z_e(Ku) - DFR$ relationship for each particle type

❑ Dataset

GPM/DPR matched with ground-based hydrometeor identification (HID) data from the GPM Validation Network (GVN) dataset are used to validate simulation results. We used measured apparent radar reflectivity factor above the height of 263.15 K, since attenuation resulting from absorption by ice particles is very small at both Ka and Ku bands.

❑ Validation results

Figure 2 shows that the contour plots of the radar data of drysnow and low/high-density graupel, superimposed on the simulated curves computed for aggregated and rimed particles, respectively. They are distributed along the theoretical curve of aggregated and rimed particles respectively. The diagram could separate the different characteristics between aggregated and rimed particles (Figure 3).

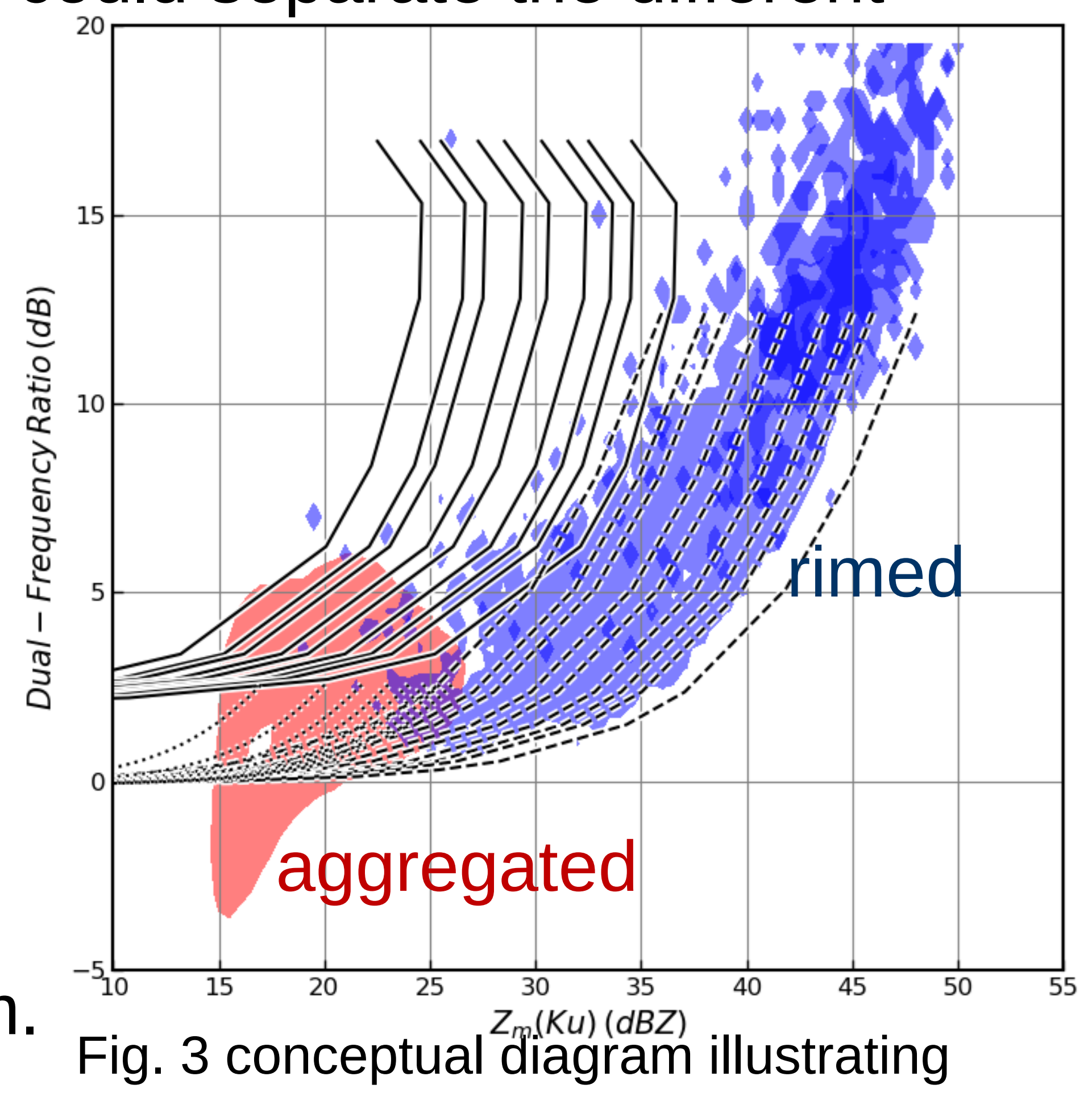

Fig. 3 conceptual diagram illustrating aggregated and rimed particles.

Summary

We explore the capability of the GPM/DPR for separation of aggregated and rimed particles. We assumed the m−D relationship for each particle. The DFR−ZKu diagram could separate them.

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