

Mass and mean size dual-frequency radar relations for frozen hydrometeors

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Abstract— Airborne in-situ frozen Particle Size Distribution data from the TRMM field campaigns is used to develop mass and mean size dual-frequency radar relations.

Keywords— radar relation; dual-frequency; frozen hydrometeors

I. INTRODUCTION

Airborne in-situ measurements of frozen hydrometeors from the Tropical Rainfall Measuring Mission field campaigns, described in [2], are used as the basis for a study to develop mass and mean size dual-frequency radar relations for the retrieval of frozen hydrometeors aloft. Radar reflectivities are calculated by integrating the particle size distributions with the appropriate Mie coefficients.

The mass (M) and mass-weighted mean diameter (D^*) are two straight-forward quantities that can be used to describe the particle size distribution. That is, a bulk quantity and a shape parameter, which is about all that one could likely hope to retrieve from dual-frequency radar measurements. They are not parameters from some fit function, so that, the goodness of fit is not a concern. They are immune to many of the problems associated with fitting continuous functions to discrete distributions, such as, truncation [4][5] and biased moment ratio methods to calculate parameters.

$$D^* = \frac{\sum_i M_i D_i}{\sum_i M_i} \quad (1)$$

However, M and D^* are not independent which makes for an odd basis, complicates the retrieval process and interpretation of results. Following the methodology of [1], a mass uncorrelated mass-weighted mean diameter D' is calculated as

$$\begin{aligned} \log D' &= \log D^* - \alpha \log M \\ \Rightarrow D' &= D^* M^{-\alpha} \end{aligned} \quad (2)$$

with

$$\alpha = 0.2326 \quad (3)$$

To illustrate the relationship between hydrometeor mass and dual-frequency radar measurements, fig. 1 and 2 show the mass divided into five range classes on a scatter plot of

$(dBZ_{14}, (dBZ_{14} - dBZ_{94}))$ and $(dBZ_{35}, (dBZ_{35} - dBZ_{94}))$ respectively. It can be seen that the single frequency reflectivity rather than the differential reflectivity is more sensitive to changes in the mass. The mass classes are tilted, so that a single frequency alone will not provide a good measure of the mass by itself, which is a result of shape changes in the particle size distribution and their effect on reflectivity.

In a similar way, figures 3 and 4 illustrate the relationship between D' and the dual-frequency reflectivities at two sets of frequencies (14 GHz, 94 GHz) and (35 GHz, 94 GHz). In this case the D' classes are oriented differently from the mass classes in figures 1 and 2, which signifies the first-order independence of the two quantities as projected onto the dual-frequency measurements and highlights the usefulness of such a choice of variables to describe the particle size distribution. Unfortunately, neither of the two sets of classes are oriented along the axis of the reflectivities, nor are they rotated by ninety degrees from each other.

II. LOOKUP TABLES

Instead of dividing the the reflectivity space by mass and D' , tables are compiled that give the expected values of D' and M respectively for discretized values of the dual-frequency reflectivity space, dBZ_{14} versus $(dBZ_{14} - dBZ_{94})$. Such lookup-tables can be incorporated into a retrieval algorithm similar to that used for dual-frequency measurements of rain described in [3].

In turn analytical relations have been fitted to the data in above mentioned tables, resulting in

$$\begin{aligned} \log_{10} M &= -0.644 + 0.07 dBZ_{14} \\ &\quad - 0.112 (dBZ_{14} - dBZ_{94}) \\ &\quad + 0.002 dBZ_{14} (dBZ_{14} - dBZ_{94}) \end{aligned} \quad (4)$$

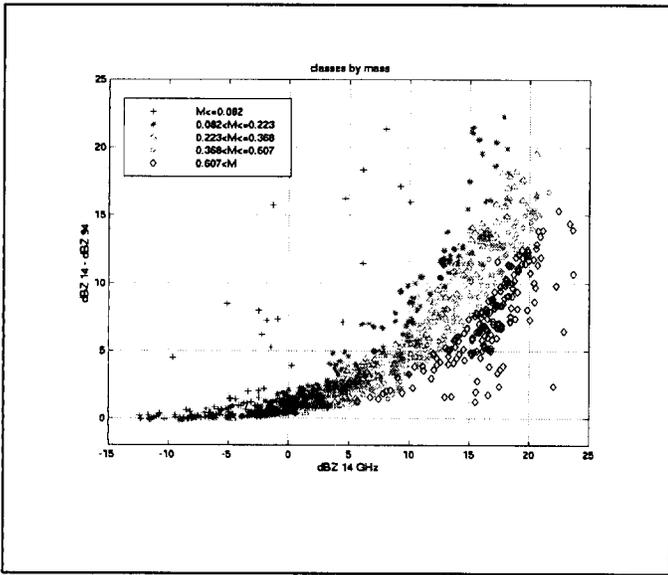


Figure 1. Plot of dBZ 14GHZ vs (dBZ 14GHZ – dBZ 94GHZ), partitioned by mass ranges in different colours

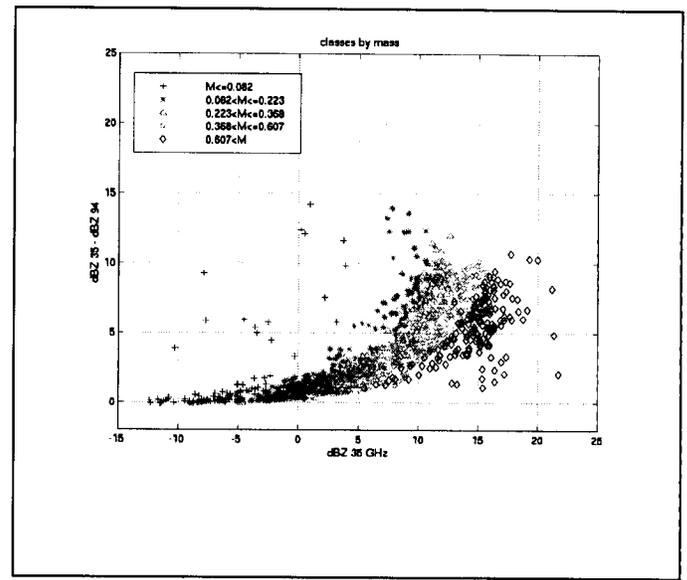


Figure 2. Plot of dBZ 35GHZ vs (dBZ 35GHZ – dBZ 94GHZ), partitioned by mass ranges in different colours

$$\begin{aligned}
 \log_{10} D' = & -0.29 - 0.0048 dBZ_{14} \\
 & + 0.075 (dBZ_{14} - dBZ_{94}) \\
 & - 0.008 dBZ_{14} (dBZ_{14} - dBZ_{94}) \\
 & - 0.0002 dBZ_{14}^2 - 0.0002 (dBZ_{14} - dBZ_{94})^2
 \end{aligned} \quad (5)$$

Fits with different degrees of polynomials have been tested, the final selection criteria was to obtain an adequate fit with the least possible terms.

One of the advantages of obtaining analytical relationships, is that they can be utilized to provide solutions for regions of the measurements space that contain no in-situ measurements. The lookup tables described above have many sparse areas, although the validity of solutions for such areas is questionable. But none the less there will be (M, D') solutions for all possible reflectivity measurements.

The error associated with the fitted relations Eq. 4 and 5 can be calculated as the difference between the fitted values obtained using equation Eq. 4 and 5, and the in situ calculated quantities, normalized by the standard deviation for the individual table grid boxes.

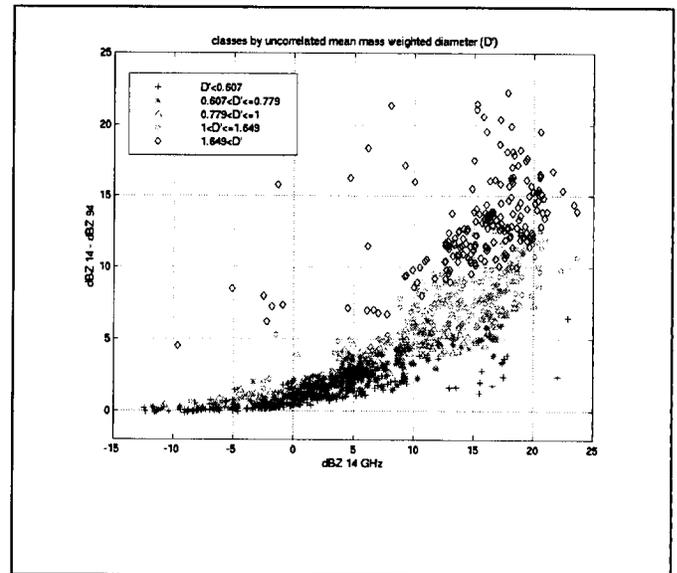


Figure 3. Plot of dBZ 14GHZ vs (dBZ 14GHZ – dBZ 94GHZ), partitioned by mass uncorrelated mass-weighted mean diameter (D') ranges in different

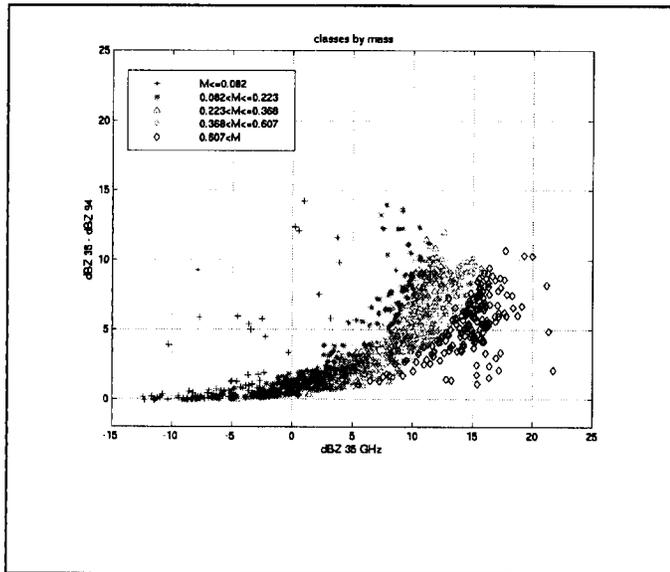


Figure 4. Plot of dBZ 35GHz vs (dBZ 35GHz – dBZ 94GHz), partitioned by mass uncorrelated mass-weighted mean diameter (D') ranges in different colours

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