Title: Estimation of vertical profiles of raindrop size distribution and cloud microphysical processes in stratiform rainfall using vertical-pointing X- and VHF-band radars

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We greatly appreciate all your comments, instructions, and suggestions for our paper. Our response is written in blue.

This manuscript describes a method to estimate the gamma raindrop size distribution parameters using moments from a vertically pointing X-band radar and the air motion retrieved from a VHF wind profiler. Since the X-band radar did not record the Doppler velocity spectra, the DSD parameters were retrieved from measured moments of reflectivity, mean Doppler velocity, and spectrum width. The manuscript does a nice job of describing the spectrum broadening terms (i.e., due to horizontal wind, turbulence, and shear) that contribute to the measured spectrum width, provides an error analysis, and estimates the DSD uncertainties when not including those correction terms. After clarifying a couple minor items, I believe this manuscript would be ready for publication.

We greatly appreciate such encouraging comments. We have provided our responses to each comment below.

Specific Comments:

1. Equation (4). I do not think equations (4) and (8) are correct. From Fukao and Hamazu, the spectrum width is given by equation (5.102). The second term in equations (4) and (8) appear consistent with (5.102), but the first term is not consistent with equation (5.102). Also, to me, it does not look correct to have the mean air motion V_a(overbar) included in the spectrum width estimate. The spectrum width calculation is the width of the rain portion in the spectrum (see Fukao and Hamazu, Fig. 5.10). If V_a(overbar) is replaced with V_tz^nonRay(overbar) in equation (8), then would the spectrum width be just the first term in equation (8)? For equation (4), the text would need to define a similar variable called V_tz^Ray(overbar) for equation (4). Please examine equations (4) and (8) and make changes where needed.

Thank you for your comment. As you correctly surmised, we intentionally included $\overline{V_a}$ to account for the background wind present in the real atmosphere. However, we agree that mathematically these terms cancel out, and for the definition of spectral width, the form excluding $\overline{V_a}$ (as in equations 5.102 and 6.17 in Fukao and Hamazu, 2014) is physically the most concise and accurate.

Please note that when excluding $\overline{V_a}$ in our equations 4 and 8, they are consistent with equation 6.17 in Fukao and Hamazu (2014). Equations 5.102 and 6.17 in Fukao and Hamazu (2014) are equivalent.

The description was redundant and potentially misleading, so we will revise the equation.

2. Lines 246-247. As written, I thought the phrase 'liquid phase' is referring to the Rayleigh scattering peak observed by the MU radar, but it appears to refer to the height region containing rain drops (aka, liquid phase). Please clarify that the 'liquid phase' refers to a height region containing liquid phase hydrometeors and not to the hydrometeors themselves.

Thank you for your feedback. We will change the description to "at all altitudes in the liquid phase."

3. Line 370. Is a word missing? How about, '...found that the XRAIN K_DP is sensitive..."

We apologize for the typo. We will correct it as you suggested.

4. Line 518. Attenuation in TAMX is discussed, but attenuation in NUX is not discussed. At these short ranges and larger particle regimes during stratiform rain, I do not believe that attenuation will impact the N0 estimate very much. But please confirm that assumption and please provide a sentence or two near equation (20) that discusses how attenuation in the measured NUX reflectivity is ignored or included in the estimate of N0.

As you pointed out, we have not taken into account the influence of NUX attenuation. The maximum observation height in this study is approximately 3 km from the NUX installed altitude. Even assuming a relatively high rain rate for stratiform precipitation (e.g., 12 mm h^{-1} $\approx$ about 40 dBZ from $Z^* = 200R^{1.6}$ in Marshall et al., 1955), the specific attenuation at X-band is estimated to be around 0.2 dB km^{-1} ($A = 0.011R^{1.15}$ of Table 6.1 in Fukao and Hamazu, 2014). Consequently, the total two-way attenuation over the 3 km path would be about 1.2 dB in the worst case. Although this value corresponds to an error of approximately 24% in linear reflectivity Z^* and consequently in N_0, we consider this error acceptable for the purpose of this study.

We acknowledge that attenuation accumulates with height, which creates an artificial vertical gradient in the reflectivity profiles (i.e., underestimation increases with height). However, the magnitude of this artificial gradient in the worst case is estimated to be roughly 0.4 dB km^{-1} (two-way). In contrast, the microphysical processes discussed in this study (e.g., evaporation, coalescence, and breakup) often cause larger vertical variations in radar reflectivity (Fig. 15a in the text). Furthermore, considering the NUX vertical resolution of 150 m, the difference of attenuation between adjacent range bins is estimated to be only about 0.06 dB. This slight increment is negligible compared to the measurement fluctuations. Therefore, although attenuation creates a slight artificial trend, it is not significant enough to mask the physical vertical evolution or alter the conclusions. We will add sentences near Equation 20 to clarify this assumption.

These are our responses to your comments and suggestions. Thank you in advance for your kind attention.

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References

Fukao, S. and Hamazu, K.: Radar for meteorological and atmospheric observations, Springer Tokyo, doi:10.1007/978-4-431-54334-3, 2014.

Marshall, J. S., Hitschfeld, W. and Gunn, K. L. S.: Advances in radar weather. *Advances in Geophysics*, Vol. 2, Academic Press, 1–56, doi:10.1016/S0065-2687(08)60310-6, 1955.