Response to Review1

This is an interesting paper that explores the use of very high-resolution radar to characterize drizzle drops in a large cloud chamber. The authors find that identification of single drop backscatter against the background cloud droplets is very challenging and at best requires multiple hours to expect observation of a single droplet. While the authors remain optimistic that such a radar can be used for this purpose, its seems that this optimism is a bit premature since the shortest time for detection (order of hours) relies on a droplet concentration theory that, while plausible and published, is perhaps a theory that cannot yet be relied upon to be mature.

I can find no technical issues with the paper and I think it could be published as is. However, I do think the authors should consider a more realistic assessment of the challenges of this methodology being successful. For instance I question whether a 3-hour observational interval between detecting drizzle drops is reasonable? Can the cloud chamber remain in steady state for this long? What exactly can be learned by sensing the presence of a single drizzle drop every several hours? Is drizzle actually produced for the liquid water contents that seem most suitable for generating the SNR needed for detection (much less than 1 g/m3)?

Response:

We appreciate the reviewer's acknowledgement on our work, and we agree that a more realistic assessment is necessary for the drizzle detection method. However, the main focus of this study is to propose the concept of detecting single particle using high-resolution radar in cloud chamber. We have demonstrated this concept using theoretical model and real-chamber observation. A full assessment of the proposed method, while is necessary, is not decided to be added in the manuscript as this work is beyond the scope of this study.

For instance, to answer the questions mentioned by the reviewer. A more realistic cloud chamber simulation should be conducted in combination with a full consideration of the radar capability. To be more specific, the spatial and temporal information of the drizzle particles in the cloud chamber should be known, the associated radar sampling strategy, range resolution and the Signal to Noise Ratio (SNR) should be considered. That is to say, the 3-hour observational-internal discussed in the manuscript is just an example showing the significantly reduced observational time after considering the collision-coalescence process. This example does not provide specific guidance or quantitatively estimation on the drizzle detection time in real cloud chamber. Depending on the chamber environment, radar scanning strategy, SNR, and the size of particle to be detected, the detection time would vary signifyingly. A more realistic and comprehensive assessment of the proposed drizzle detection approach will be conducted in our future study.

Minor issues:

The manuscript should be proofed for grammar.

Response: Thanks for the comments. We have carefully proofread the manuscript, addressing grammar, spelling, and punctuation errors in the revised version.

Line 56: Is there documentation of this inability to explain drizzle growth by "traditinally-defined condensation growth processes"? It seems that a single 1996 paper is insufficient to establish this statement which is the motivation for using the cloud chamber to study the process

Response: More related references have been added in the revised manuscript to support the statement.

Line 65: What effects?

Response: We have modified this sentence in the revised manuscript:

Line 65: "…One main barrier that hinder our ability to investigate the drizzle initiation process is the lack of observations with sufficient sensitivity and spatiotemporal resolution to detect the early growth of drizzle particles…"

Figue 2: Color scheme is not friendly to color-blind readers.

Response: The color scheme has been modified to be more colorblind-friendly.

Line 235: The likelihood of getting 40 micron drizzle drops in an 0.2 g/m3 LWC cloud seems very unlikely.

Response: We want to thank the reviewer's comments. In Zhu et al. (2022), we have demonstrated that drizzle-size particles are ubiquitous in nature and can be generated in clouds with Liquid Water Path(LWP) lower than 50 g m^{-2}. Thus, we tend to consider that the formation of 40-micron particle in cloud chamber with 0.2 gm^3 LWC is plausible.

Response to Review2

The paper is a fascinating study exploring the potential of radar with ultra-fine sampling volume to increase the possibility of detecting tiny drizzle drops in small concentrations in a cloud chamber. Practical experiments also support the analytical analysis. The study has relevant implications for gathering knowledge on aerosol-cloud interaction and microphysical processes leading to warm rain formation, and for this, I recommend its publication. My only primary concern is that most graphics are color-blind people unfriendly. I suggest that the authors re-elaborate them after exploiting tools to check their plots, which can also be found at https://hiweller.rbind.io/post/using-the-dichromat-package-to-check-if-your-plot-is-colorblind-friendly/

Response: We want to thank the reviewer for the positive feedback on this study and for providing valuable suggestions. We have modified the color scheme to make the figures to be more colorblind-friendly.

Moreover, I collected some minor comments, corrections of typos, and mere curiosity questions, which I list here:

Under which hypothesis do you assume the same distribution used for cloud droplets is also valid for drizzle? I understood that you used eq 6 to describe the N(D) of the drizzle drops in 9, and I would like to understand more about this choice.

Response: We want to thank the reviewer's comments. In Sec. 4, the main focus is to demonstrate the trade-off scenario that the probability of particle occurrence in a radar volume decreases significantly as the volume decreases. In this regard, a theoretically derived DSD (i.e. Eq. 6), which is required in Eq.9, is qualitatively adequate to illustrate this effect. However, we agree with the reviewer that Eq. 6 might not represent the experimental probability of occurrence for drizzle particles. To achieve a more realistic droplet size distribution, we apply the ClusColl model to illustrate the caveat of application of Eq. 6 for drizzle occurrence estimation (shown in Fig. 6).

L 237: Is it possible to also include, as a reference, dots representing typical in real situ observed relations of LWC/N in Figure 2, as you did for the ones observed in the cloud chamber? It would show how representative the cloud chamber of what happens in reality is—for example, one or two cases of warm maritime and continental clouds from literature studies.

Response: We thank the reviewer for the suggestion. As the focus of this manuscript is on drizzle detection in a cloud chamber, we decided not to link drizzle detection in real cloud observations because this additional information would be distracting and is not directly related to the research topic. Instead, we add the following statement in the manuscript to emphasize the difference between cloud in a chamber and cloud in the atmosphere:

"…It should be noted that LWC_c and N_c in a convection cloud chamber have a stronger correlation compared with those in atmospheric clouds (Shaw et al., 2023)"

Fig 3: I think that adding a grey grid on the background of the plots would help the reader to follow your arguments.

Response: The corrections have been made.

L 264: Where is the 70-micron case?

Response: The corrections have been made.

L 240: … probability of “detecting, " not detection.

Response: Corrections have been made.

L 481: Do you think the high inhomogeneous variability in the cloud droplet distributions is happening only in the cloud chamber, or is it a property that can also hold for real clouds? Here, and in general, in the whole paper, it would be great to have a more evident connection to the cloud observations in the environment, maybe highlighting how these studies in the cloud chamber can support them and also discussing possible limitations and differences between what occurs in the cloud chamber and what happens when taking observations outside.

Response: We want to thank the reviewer for the comments. In-situ observations have shown that droplet size distribution can also vary in real clouds, especially near the transition region between cloudy and clear air (Beals et al., 2015). Thus, when detecting drizzle drops in real clouds using small radar sampling volume (if possible), we also need to consider the impact of “background-noise” fluctuation on drizzle detection. However, drizzle detection in atmospheric clouds would encounter more complicated challenges compared with the detection in a cloud chamber, due to the complexity of microphysics and dynamics in real clouds. A more detailed and comprehensive assessment of the application of high-resolution radar for drizzle detection in real clouds will be conducted in our future study.

Reference:

Zhu, Z., Kollias, P., Luke, E., and Yang, F.: New insights on the prevalence of drizzle in marine stratocumulus clouds based on a machine learning algorithm applied to radar Doppler spectra, Atmospheric Chemistry and Physics, 22, 7405-7416, 2022.

Beals, M. A., Fugal, J. P., Shaw, R. A., Lu, J., Spuler, S. M., and Stith, J. L.: Holographic measurements of inhomogeneous cloud mixing at the centimeter scale, Science, 350, 87-90, 2015.

Shaw, R. A., Thomas, S., Prabhakaran, P., Cantrell, W., Ovchinnikov, M., and Yang, F.: Fast and slow microphysics regimes in a minimalist model of cloudy Rayleigh-B\'enard convection, Physical Review Research, 5, 043018, 10.1103/PhysRevResearch.5.043018, 2023.