Referee's Comment on "The Critical Number and Size of Precipitation Embryos to Accelerate Warm Rain Initiation"

Title: The Critical Number and Size of Precipitation Embryos to Accelerate Warm Rain Initiation
Author(s): Jung-Sub Lim et al.
MS No.: egusphere-2024-2636
MS type: Research article

General Comments

This paper offers a fresh perspective on the role that rare large droplets, here named "precipitation embryos (PEs)", can have on precipitation formation from a droplet distribution which would otherwise undergo slower collision-coalescence (akin to the "luck-drops" theory). The study is well-motivated and the use of the super-droplet model throughout is particularly appropriate. The conclusions drawn are well-grounded and are worthwhile for our understanding of the timing of rain formation. They certainly further our knowledge of how sufficiently numerous and large droplets can accelerate droplet collision-coalescence, and they also give particularly useful insight to how turbulence-induced collision enhancement (TICE) - another process known to accelerate rain formation - can either complement or inhibit the acceleration caused by large droplets. Indeed I believe the study to be within the scope of ACP and I recommend that the editor consider publishing this work. Nevertheless I have some specific comments I would like to see addressed first, particularly with regard to section 3 and the decision to truncate the droplet size distribution (DSD) for almost all the analysis.

Specific Comments

Points throughout the manuscript:

Most critically, I am unconvinced by the decision to truncate the DSD at 20μm and I believe the analysis and conclusions of the paper would be clearer if they were presented without this cut-off. The truncation is justified as creating a "stable initial DSD in which collisions are negligible" however, as for example the black lines in figure 6 show, the truncated DSDs do undergo frequent collisions and so the truncation appears unjustified. Contrary to the Author's introduction, I believe such examples also mean the role of "precipitation embryos" (PEs) in inducing collisions in an otherwise stable distribution is not addressed in this paper. The paper is better introduced as showing how PEs can accelerate the timing of rain formation for a DSD in which droplets *already can* collide. I am of the opinion that the analysis would be clearer, and the conclusions more convincing, if the cut-off was removed. For example the red and green lines in figures 4(a) and 4(b) (i.e. the RM12 and RM14 setups) show large changes between figures 4(a) and 4(b), and 4(c) and 4(d), ie. when the un-truncated distribution is used instead. Likewise figure 5 shows large differences in the results without truncation. This means the behaviour of the critical threshold is heavily influenced by the cut-off at 20μm and the analysis of the role of PEs, particularly in section 3, would be more convincingly shown if that influence wasn't present.

Points regarding certain lines within the manuscript:

- L3 (and repeated): please reconsider the use of the term "colloidally stable". The terminology is misleading because it is conventionally used to discuss the condition of a colloid substance - i.e. the mixture of soluble and insoluble substances in a solute.

- L22 ("so-called precipitation embryos (PEs)"): is the term "precipitation embryo" coined in this paper? If not, please provide a citation here. If so, please consider if there is any existing terminology you can use instead. Why for example is the term "lucky droplet" not appropriate?

- L81 ("N_0 = 238 cm^{-3}, 456 cm^{-3} and 523 cm^{-3}"): the values for N_0 given here do not match those in the legend of figure 1 so please correct them. Also it would be clearer if their order was consistent with the ordering of $\bar{r}$ in the sentence before (i.e. if $\bar{r}$ is ascending, N_0 is descending).

- Figure 1: These DSDs do not show very clearly the alteration you make by truncating these distributions, nor do they show the impact of adding PEs on them. It would be helpful to the reader to include a neighbouring figure (or to replace this one) with a plot that shows the truncated DSDs and some DSDs which example the distribution with $n_{\mathrm{PE}}, r_{\mathrm{PE}}$ values.

- L96 ("To explore the impact of PEs, we investigate 49 ensemble simulations…"): it's quite important that this is justified with a comparison to the real world. How do these PE radii and number concentrations compare with observations? Especially relevant would be to put them in the context of shallow convective clouds, since that's the range of TICE you consider later on, or cloud seeding. Context is particularly necessary because figure 2 shows both μ_{100} and $\mu_{10\%}$ have almost no dependency on a large portion of the $n_{\mathrm{PE}}, r_{\mathrm{PE}}$ space spanned by the ensemble.

- L102 ("larger PEs can substantially increase the initial q_c"): please state how much your simulations are perturbed by the presence of PEs. For example stating what the largest q_c of your ensemble is (when $(n_{\mathrm{PE}}, r_{\mathrm{PE}}) = (1000,18)$).

- L213 ("although t_{100} can be shorter than in the cases without PEs."): please provide a suggested explanation or citation for this statement.

- Figure 6: With increasing PE concentration, the accretion and auto-conversion rates due to *non-PE* collisions maximise earlier. A acknowledgement and a possible reason for this behaviour would be beneficial because it is not self-evident why it should occur.

Technical Corrections

Points regarding certain lines within the manuscript:

- L11 ("A key question in warm rain initiation is to explain..."): There is no question posed here, consider rephrasing the second half of the sentence into a question, or rewording "a key question".

- L36 ("In particular, if we consider ... Thus, it is also important to account for stochastic fluctuations in the collision process."): please rephrase this sentence because this logic is hard to follow. I was left asking myself: why is a 12.5μm droplet relevant to your study, and how does this citation justify the need for stochastic fluctuations? I assume you mean than by including stochasticity you don't need as large lucky droplets to initiate collisions, but please make this more explicit if so.

- L56 ("frequently called superdroplets by introducing a weighting factor"): please add missing comma after "superdroplets".

- L110 ("The timescale t_10% represents the time when 10 % of the initial cloud droplet mass converts to rain…"): is rain here defined as above 40 or 100 microns?

- L145 (equation 6): Missing subscript α on Φ on the left-hand side of the equation.

- Figure 4 and figure 5: Please reconsider the colours you use to plot these figures because they are unkind to colour-blindness (especially figure 4). Also in figure 4, the re-use of the same colours for subplots (e) and (f), although they are no longer denoting different $\bar{r}$, is undesirable.