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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Competition for water vapour results in suppression of ice formation in mixed phase clouds" *by* Emma L. Simpson et al.

Anonymous Referee #1

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The core idea in this paper is that high concentrations of CCN can inhibit the formation of ice through a Wegener-Bergeron-Findeisen (WBF) type effect, where soluble particles activate and reduce the local supersaturation enough that it prevents the ice nucleating particle from acquiring enough water to support formation of a critical embryo. This is an intriguing idea, but there are some serious gaps in its presentation in this paper. I am not opposed to publication, but some of the points below need to be addressed.

The experiments do not contribute much to the paper. The sentence on page 9 (line 13) is the clearest statement of this. "However no suppression of ice was observed." While I admire the authors' honesty in explicitly stating this, it calls into question the premise of having the experiments in the paper at all. The next statement in the manuscript

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is an explanation of why they didn't see the suppression and how it is consistent with the results from simulations. If the model doesn't show suppression of ice formation in this parameter range, why not run experiments in the range where the model **does** show suppression? That might not be possible, but if it isn't that should be stated and explained.

Once it is established that the experiments do not show the paper's core idea, the purpose seems to be a refinement of nucleation parameterizations of the various dusts that were used in the study. I do not find these results convincing enough to justify using any of the criteria listed in Table 1. (There are criteria in Table 1 that I find compelling. See next paragraph.) If a better curve fit is the goal, why not just modify the original parameterization?

In the end, the claim that freezing only proceeds with some critical amount of water is reasonable. There is evidence to support it. For example, Sanz et al have calculated the size of the critical embryo as a function of supercooling. Li's work also indicates that the nucleation rate in constrained volumes can differ from the bulk. But results from a cloud chamber are unlikely to experimentally confirm these findings. There are too many other explanations that are also likely that could be invoked. (Please see the question concerning heat leakage into the chamber in **Miscellaneous**.)

Suppression of ice formation is more clearly supported by the simulations. I agree that a minimum amount of water is needed (setting aside deposition nucleation, for the moment), even if I am not convinced that the measurements show this. There is an aspect of the simulations that is not discussed as well as it should be though. There is an implicit assumption that the ice nucleating particles are submicron. While most of the ice nucleating particles that have been measured in the atmosphere are submicron, this is, in part, an artifact of the measurement technique. For example, in most Continuous Flow Diffusion Chamber measurements, the larger particles are intentionally excluded because the discrimination between liquid water and ice is done on the basis of size. There are results showing that particles larger than a micron are an

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appreciable fraction of atmospheric ice nucleating particles (Mason et al 2016). If you consider ice nucleating particles in that size range, the argument based on competition for vapor starts to break down. The critical supersaturation for a 1 micron particle with a kappa value of 0.01 is 0.04%, which is comparable to an ammonium sulfate particle of 250 nm diameter. With those values in mind, I do not find CCN "outcompeting" ice nucleating particles as compelling.

In summary, the idea that ice formation could be suppressed because of competition between numerous CCN and ice nucleating particles is an intriguing one, but the chain of reasoning presented here should be tightened.

Miscellaneous

Do a global search for "preform". This occurs in several places in the paper, and I am almost certain that it should be "perform".

Similarly, search for "modelling". Delete one of the "l"s from that word.

Page 8, line 3: "were" not "where"

The reference to Rogers and Yau on page 7 (line 18) is not needed. If you are going to cite it, please at least provide a chapter or section. That book covers a lot of topics.

The reference to Kumar 2009 on page 14, line 12 should be in parentheses.

Is there a leakage of heat into the experimental chamber? There's a substantial difference between thermocouple 1 and thermocouple 8 by the time you get to 250 seconds after expansion starts. Could that be part of the reason you see the decrease in ice crystal concentrations as a function of time? (I would have expected to see ice crystal concentrations increasing or at least staying constant since the counters are at the bottom of the chamber and crystals from above are continuously falling into the field of view.)

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