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Atmospheric Measurement Techniques
Discussions

Interactive comment on "A new method for operating a continuous flow diffusion chamber to investigate immersion freezing: assessment and performance study" *by* Gourihar Kulkarni et al.

Anonymous Referee #1

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The Kulkarni et al, study describes a newly developed operating procedure for investigating the immersion freezing mechanism using continuous flow diffusion chambers. The new method converts the typical nucleation section of such chambers into a "conditioning" section where the aerosol particles are activated into cloud droplets at a fixed temperature where no freezing is expected. Then the particles transition into the newly dubbed "nucleation section" (formerly known as the evaporation section), which is cooled continuously while maintaining ice saturation. The newly developed technique compares well with previously published immersion freezing methods, although it appears to produce higher frozen fractions (within an order of magnitude) than previously observed for several dust species. I find the new method to be well implemented and a

nice addition to the ice nucleation measurement community. I support this manuscript for publication and have the following comments:

General comments:

The residence time of the instrument is described as $\sim$10 seconds, yet the actual nucleation section is only half of that. This is not that different from traditional CFDCs, however, when the lifetime of the evaporating droplet in the nucleation section is considered, the nucleation time seems closer to $\sim$2 seconds (according to the numerical simulations). This should be noted in the text.

Furthermore, when considering that the droplets evaporate so quickly, is it possible to retrieve some information about nucleation rates based on the observed ice crystal sizes as a function of temperature, as was alluded to for the homogeneous freezing experiments?

Throughout the text, the new method was described as "the new method". I think it would be nice if the new technique had a name for easier future reference.

I appreciate that the authors did a thorough evaluation of the instrumental design using CFD and pulse experiments. However, I found the description and justification of the settings used missing, see my comment below.

Although the authors go in depth in their comparison with the dusts tested with previous results, I found the justification for the observed differences to be rather vague. This is especially true when comparing with the observations from the FIN workshop where to my understanding, the same aerosols were being tested at the same time. Therefore it would be nice if the authors expanded on some of the reasoning as to why the results in ns can differ by up to an order of magnitude. For example, is it due to not all particles being activated in other techniques due to lamina issues or perhaps it is due to the conditions that the droplets are evaporating at (warm wall temperature or cold wall temperature) etc.?

Technical and minor comments:

Line 38-39: There is mounting evidence that the traditional view of deposition nucleation, may not be occurring. As referenced in the cited Vali et al., (2015) deposition nucleation has also been referred to as immersion freezing in pores or pored condensation and freezing (Marcolli, 2014). Consider adding pore condensation and freezing as a heterogeneous nucleation mechanism.

Line 53-54: Consider adding Garimella et al., (2017) as a reference as well.

Line 57 and 60-61: Did you test to see if all particles did indeed activate as droplets?

Line 77: Are there two sheath flows of 5 lpm of was the total sheath flow 5 lpm? Please clarify.

Line 78: With such a high supersaturation and the required temperature gradient to achieve this supersaturation, how can you ensure that all particles activated as droplets?

Line 91-93: Here the temperature gradient between the walls is mentioned and the achieved temperature of -20 C is described in the following sentence. However, it may be worthwhile to specify the supersaturation of the conditioning section here as well (113 % RHw?).

Line 99-102: This should be reworded, consider something like: "The isothermal conditions of the nucleation section is maintained at ice saturation and cooled at a steady rate (0.5°C min-1 100) by a separate cooling bath in order to determine the immersion freezing efficiency of INPs as a function of supercooled temperature"

Line 102-103: Why does the experiment proceed so far below the homogeneous freezing temperature?

Lines 110-112: Was there any gradient applied to the conditioning experiment during the pulse experiments? I find this unclear in the text. Furthermore, if a temperature

gradient was applied in the conditioning section, are there any effects from the ice coating/ moisture from the walls on the buoyancy profile of the air in the chamber that are missed by doing the test without an ice coating? Also, are there any impacts on the lamina of the chamber when going from the conditioning section to the nucleation section when there is a temperature gradient of 22 C (-20 to -44 C)?

Line 183: remove "either" before "do"

Line 184-186: Please clarify these sentences. Are the smaller droplets at higher temperatures due to the lower nucleation rate and therefore the droplets evaporate more than at colder temperatures where nucleation is faster?

Line 183: Remove "the" between "of" and "supercooled"

Lines 191-195: seem to be contradicting each other, consider rewording.

Line 200-224: Consider breaking this sentence in two for easier readability.

Line 206: Rather than stating "a new mode" perhaps consider stating that it is operated in this specific mode (name the mode).

Line 223-224: Consider rewording.

Line 245-246: Earlier, it is stated that an experiment ends at -44 C yet now the experiment ends at -38, which makes more sense, be sure to be consistent.

References

Garimella, S., Rothenberg, D. A., Wolf, M. J., David, R. O., Kanji, Z. A., Wang, C., Rösch, M. and Cziczo, D. J.: Uncertainty in counting ice nucleating particles with continuous flow diffusion chambers, Atmos Chem Phys, 17(17), 10855–10864, doi:10.5194/acp-17-10855-2017, 2017. Marcolli, C.: Deposition nucleation viewed as homogeneous or immersion freezing in pores and cavities, Atmos Chem Phys, 14(4), 2071–2104, doi:10.5194/acp-14-2071-2014, 2014. Vali, G., DeMott, P. J., Möhler, O. and Whale, T. F.: Technical Note: A proposal for ice nucleation terminology, Atmospheric Chem. Phys., 15(18), 10263–10270, doi:10.5194/acp-15-10263-2015, 2015.

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