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Atmospheric Measurement Techniques Discussions

Interactive comment on "A Phase Separation Inlet for Droplets, Ice Residuals, and Interstitial Aerosols" *by* Libby Koolik et al.

Anonymous Referee #3

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This manuscript provides a detailed description of the design of a 2-stage pumped counterflow virtual impactor for sampling droplets, ice residuals, and un-nucleated interstitial particles. This sampling system can be used as the front end for various downstream sensors, including optical particle counters and mass spectrometers. The value of this technique is to clearly and cleanly separate cloud residuals, which are linked to the nuclei for cloud droplet and ice formation, so that their properties can be measured. This is extremely important because of the strong leverage that the very few particles that serve as ice nuclei have on cloud radiative properties and lifetime, and thus climate.

The manuscript is very thorough and provides a good description of the instrument characteristics and performance. Laboratory studies on aerosols, droplets, and flash-

frozen droplets, are analyzed, and ambient data collected for a few days at the Storm Peak Laboratory in Colorado shows that the technique works in a field environment. The manuscript is generally well-written. However, it tends to get bogged down in minutiae, and needs to be tightened considerably for clarity. I make suggestions for how to reduce the length and recommend that the manuscript undergo major revision to complete these edits. Since the content is good (i.e., no new experiments need to be conducted), this editing should be straightforward (if unpleasant).

Major comments: 1) Move Section 3.2, which describes the start-up procedure, to the Supplemental Materials. Very few readers will be interested in the details of the order in which flows are started.

2) Lines 172-175. Please describe these optical particle counters in more detail. Are they used to count particles or to measure size distributions? What is their size resolution (e.g., bins per decade of particle size). Are they white-light or monochromatic? Do they suffer from sizing ambiguities due to Mie oscillations? What are their flow rates and uncertainties?

3) Line 177. Please describe the PROTeGE wet particle generation system in one sentence–what does it do, and over what size range? Does it produce a monodisperse or polydisperse aerosol?

4) Lines 200-201. Is this shift in residual size from 3.7 μm dry size to a 4.7 μm droplet residual a result of incomplete evaporation, or is it just the sizing resolution of the OPS? We don't know enough about the OPS response to evaluate whether this discrepancy is significant (see comment (2) above).

5) Line 203. When the pumping flows are turned on, shouldn't the residence time in the sample flow increase because much of the flow is being pumped away? Wouldn't this lead to better evaporation of the particles and a size closer to the expected 3.7 μm than the test without the pumping flows (and thus a shorter residence time)?

6) Table 1 has only one row, and this information could probably go into a single sentence in the manuscript.

7) There are 17 figures, which is just too many for a relatively concise technical manuscript. Several figures contain peripheral information that could be moved to the Supplemental Materials without any loss of content for the vast majority of readers. These figures include Figs. 3, 4, 8, and 15. Figure 10 and the associated discussion in the text could be eliminated entirely, unless the authors provide a compelling reason to keep it. It distracts from the main thrust of the manuscript. Similarly, Fig. 13, which introduces data from an SMPS (which is not described in any way in the manuscript) doesn't really seem relevant to the topic of the paper. Presumably the SMPS is a scanning mobility particle sizer, which is generally heavily weighted toward particles too small to serve as IN in most environments, and so is really a tangent to the main topics of the manuscript.

8) Figure 16 is just a blow-up of a section of Fig. 14. I recommend that these figures be combined, with the shading added to Fig. 14 and Fig. 16 eliminated.

9) The caption for Fig. 14 is for a different figure. The top row of Fig. 14 appears to be data from a cloud probe, and the lowest row to be data from the L-PCVI (which also appears in Fig. 16). I have no idea what the middle row is. Some legends would be helpful for quickly reading the figure. As I mentioned, I don't see a need to replicate the data in Fig. 16; the data are pretty clear in Fig. 14.

10) All of the size distribution figures (e.g., Figs 6, 9, 10 (if kept)) and 17 should be converted to follow the dN/dlogDp convention. They are currently histograms that are not normalized by bin width. Thus any peaks in the distribution could just be caused by a wider diameter bin than other bins in the distribution, rather than an actual peak in the probability distribution function. It's too much to expect the reader to look at the diameters labeled on the axis (in a tiny font) and try to figure out if all the bins are the same logarithmic increment or not. A more traditional PDF display using dN/dlogdDp

with a log x-axis would be much appreciated.

11) On many of the figures, the font weight is too light to be quickly and easily read. In Figures 3, 4, and 8 (hopefully moved to SI), the curves are hard to distinguish. Please use a heavier line weight and colors (preferably using a palette that is visible by the color-impaired) to help distinguish them.

12) In Figure 5, please describe the meaning of the "X", arrow, and circle marks on the icons for the PCVI. This is a really clever idea to show how the sampling was set up; just describe it the first time it's used, please.

13) Figure 11 is great, but the symbols need error bars.

14) Figure 15 could be removed; just state that the ice crystal residual concentration was not correlated with wind speed.

15) In Figure 7, I don't see any distinction between "dark grey" and "light grey" bars. The text needs to more clearly describe what these bars are and how they were calculated. The rightmost bar appears to go off the top of the figure; it would be interesting to know how far up it goes. If the bars represent the range of values, there is really a LOT of spread to this measurement and it is really not too useful for interpreting performance. It could be moved to Supplemental Materials. Perhaps a box-and-whiskers presentation would be more useful than the bars?

Minor edits:

a) Line 78: "design CVI"

b) Line 123: Is there any risk of nucleating ice particles (heterogeneously) in the chamber at -16 C?

c) Line 126: Changed to "machined PCVI". It's just awkward as written, even if grammatically correct.

d) Line 155: change to "containing the same wavelength as the printer's laser".

e) Change to "Figures 5a and 5b show".

f) Lines 230-232. The first sentence says that droplets from 25-50 μm evaporate, while the second says that droplets larger than 25 μm will not evaporate. Please reconcile.

g) Line 236. Change "in the $\sim$20 μm" to "of the order of $\sim$20 μm".

h) Line 241. What does "close to the entry point of the chiller" mean. Does this mean that the droplets had to pass through extremely cold air on the way to the chamber entrance? This is rather unclear. This is not shown on the schematic diagram of the apparatus (Fig. 2).

i) Line 242. Change to "would rapidly freeze".

j) Line 254. This description is not consistent with Fig. 10b.

k) Line 287. Change to "set up"

l) Line 288: Change to "scattering signal from the Droplet Measurement Technologies. . . ." Readers may wonder why a BC detector is used for non-BC particle concentration measurements.

m) Starting with line 304, there is a lot of discussion of the minutiae of blowing snow, etc. This section of the manuscript is not very relevant to the analysis and could be condensed and the figures moved to Supplemental Materials.

n) Line 317. Change to "in the Aitken mode to fine particles in the accumulation mode".

o) Line 318: What is meant by "where coagulation and condensation are taking place"? There is little coagulation between accumulation mode particles. I'm not sure what the intent of this sentence is.

p) Line 318. Define what is meant by the "ice crystal channel".

q) Line 321: Define what is meant by the "cloud droplet residual channel".

r) Fig.1 caption. Suggest replacing "slanted" with more technical description. Are you

discussing the angle of the conical inlet? I would describe it as "more tapered".

s) Fig. 2. What are TS01-TS16 shown in the figure? I assume these are temperature sensors but they are not mentioned in the text.

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