OVERALL COMMENT: The manuscript describes the results of the study on the performance of a commercially available versatile water-based condensation particle counter, vWCPC TSI 3789, at a range of pressure conditions down to 500 hPa. The reason behind it is to gain a better understanding of the instrument behavior in potential future airborne applications. The authors investigate the vWCPC counting efficiency and the cut off size, as well as the effect of the conditioner temperature, particle material and particle number concentration at a range of pressure conditions between 500 and 1000 hPa. This is done using both laboratory experiments and numerical simulations.

The topic fits well under into the scope of the AMT and I recommend the manuscript to be accepted after the following minor points have been addressed.

Response: We sincerely appreciate the comments and suggestions from our reviewer. Thank you very much for considering the publication of our manuscript. We address your specific comments below (also in blue). The line number is corresponding to the change-tracked version.

SPECIFIC COMMENTS:

Line 10-20: Abstract: The authors may add more information such as the d50 for the vWCPC used in this study; a range of pressure settings investigated; a range of particle number concentrations, and particle material used.

Response: Thank you very much for this constructive suggestion. We revised the abstract accordingly.

Line 14: authors may want to add e.g.: “under a large range of ambient pressure conditions”

Response: we revised the sentence in line 15-16.

Line 19: “chemical composition” of particles?

Response: we revised the sentence in line 21.

Section 1: Introduction: The authors mention that non-water-based CPCs have been investigated under low pressure conditions, however, the discussion on the outcome of these studies as well as deployment of these on aircrafts is not mentioned. It would be interesting to discuss why such studies were done more often for butanol-based CPCs or other CPCs rather than for WCPCs? Win general, what are the main challenges for the implementation of CPCs on aircrafts, and what are specific challenges for WCPCs? Are health and safety concern the only advantage of the vWCPC over other CPCs in such applications? Some more discussion on that would add value to the manuscript. Although the manuscript talks about the history of CPCs and wCPCs, the literature review says nothing about the state-of-the-art CPCs or CPC-based systems currently operating on aircrafts. I think more information that is currently provided could be discussed in the context of low-pressure applications. It would be interesting to see what is currently the state-of-the-art instrumentation (i.e. CPCs) - a good example could be NMASS instrument by Williamson et al. 2018.

Response: we revised section 1 and added more discussion on the other airborne CPCs (line 61-70) and the challenges for wCPCs (line 84-85).

Line 23-44: The authors describe the history of and some new developments in CPC instrumentation. Have any of these CPCs been used on aircraft platforms or was their performance studied under low pressure conditions? If yes, that would be interesting to highlight.

Response: Thank you for this suggestion. We add a paragraph in line 61-70 mentioned two aircraft operating CPCs.

Line 56: delete the extra bracket

Response: Deleted the extra bracket. Thank you for catching that.

Line 71: The authors mention "comparable performance" – in terms of?

Response: we revised in line 115-116. "in terms of the cut-off size and detection efficiency."

Line 71-75: The authors mention that non-water-based system have been characterized under low pressure conditions. I am currently missing information on the outcome of these studies.

Response: we added the additional information of the non-water-based system in lines 61-70 and 84-85.

Line 78: "pressure dependency of the counting efficiency" - what were the results?

Response: we revised the sentence in line 122, "… and lower cut-off diameter of the CPCs usually increased with the decrease of the operating pressure"

Section 2.1 Instrument modification: The authors may consider "instrument description and modification" instead. Additional information on the instrument description could be helpful (such as the cut off size for certain particle material and temperature settings (e.g. default), detection of the maximum number concentration, default settings in terms of temperatures, new design of the growth tube.

Response: we revised the section 2.1 title and line 141-143.

Fig1: indicating which modifications were made as compared to the default unit could be helpful here?

Response: the 0.9 lpm flow from the exhaust line was filtered, passed through a flow buffer, and then made up the 1.5 lpm vacuum flow.

Line 99: "each vWCPC" - how many were used in this study?

Response: we tested three vWCPC in this study, and they had similar performances. However, we reported one vWCPC result in this manuscript. Thus, we revised the sentence to "the testing vWCPC".

The authors may want to mention somewhere in the manuscript whether the vWCPC was operating with or without water fill bottle under low pressure conditions. This is usually what's being done for butanol-based systems (butanol fill bottle stays disconnected/autofill deactivated). If that was the case and vWCPC was operating without fill water bottle connected, please provide additional information e.g for how long, and how was it ensured that such configuration did not compromise the performance of the vWCPC. What was the stability of the detection efficiency when operating in such setting? This could be added to the result section or supplemental material.

Response: the vWCPC was operated with a water fill bottle connected. We added this information in line 155-156.

Line 113: Information could be added on: the size ranges of particles used in this study, the particle material, range of pressures and number concentration investigated.

Response: we used the size-selected particles in this study. The particle material properties are listed in table S1. We revised line 169 -190. The range of operation pressure is in line 193. The number concentrations for each section were updated in the following sections.

Line: 118: There is no information provided on the CPC 3775 used in this study. I suggest adding information on d50, particle material, and working fluid. How does the response of these two models (vWCPC and 3775) compare without the constant pressure inlet? Maybe a plot could be added to a supplemental file?

Response: we revised section 2.2 and added more information about 3775 in line 194-195.

Line 123- 129: seems like a mix of results or methods that doesn't really fit under the section "Experimental characterization set up". Please revise.

Response: we revised this section 2.2 and moved some contents to the following sections 2.3 (line 204-207).

Fig.2: are these two dashed arrows that are going out of the atomizer correct? Please double check. Was either the atomizer used or tube furnace? If yes, then one line is incorrect. "Inlet pressure controller" or as in text "constant pressure inlet". Try using same name in both places to be consistent. Did you use a drier? I do not see it in the schematic. If not, please discuss why that was not the case.

Response: we revised Fig2 and section 2.2. Ammonium sulfate was the primary material for this study and was dissolved into deionized water for aerosol generation using atomization techniques. To increase the aerosol number concentration for particles less than 30 nm, polydisperse ammonium sulfate (AS) aerosols were also

passed through a tube furnace generator (Lindberg/Blue) to shift the size distribution a smaller size.

Line 132-134: The information on the particle material could be somehow linked with line 113. “this study”? Please mention particles with various composition used and their size ranges. How the set up used in this study differs from other studies e.g. where butanol-based CPCs were used.

Response: we revised section 2.2 in line 155 - 160.

Section: 2.3 Numerical simulation: Currently it is unclear whether the approach described here is the one taken in this study, or it was used in previous studies. Please make links between information provided from other studies with the current study. The authors refer to Hering’s research – what does that mean? How does the configuration and mentioned dimensions compare to the one of this study?

Response: we revised section 2.3 to explain our approach first, then summarized the current simulation findings.

Section 3: Results: the authors may consider: “Results and discussion”

Response: we revised it to “Results and discussion”

The authors divide subsections into modelled (3.2) results but under this section one finds experimental results too (e.g. Fig.6). Please revise your subchapter titles/division.

Response: we tried to show how the modeled result guides the experiments. We revised the section title to avoid confusion.

Line 159-160: the authors could combine these two sentences into one

Response: we revised line 160-190.

Line 157-158: please specify particle material and include “in diameter”. Why these sizes were used?

Response: we revised line 285. We tested more than three sizes (up to 450 nm). However, larger size particles selected by the DMA techniques are subject to more particle loss through the constant pressure controller. Thus, we presented three of sizes here (15, 25 and 100 nm).

Line 164: “lower than 500 hPa” - data below 500 hPa is currently not in the plot. However, the authors discuss the behavior below 500 hPa. Please revise this statement to match the data presented or add the data that supports that. The counting efficiency start decreasing below ~700 hPa. How does this compares with the results of the previous studies. Any potential explanation? There’s no 100 nm data point at 920 hPa. Please double check or state the reason.

Response: sorry that it is a typo. It should be "lower than 600 hPa". For 100 nm particles, we tested fewer pressure conditions to confirm the trend on the same day we tested 15 and 25 nm particles.

Line 198: please rewrite: "one 8 nm see particle grew to a smaller size"

Response: we revised "one 8 nm seed particle grew to a smaller size"

Fig. 5. add the meaning of dashed lines in the figure caption.

Response: The dashed lines indicate the starting and ending locations of the moderator.

Line 214: this subsection is called "Modelled…", however it contains both simulated and experimental results. Please revise.

Response: we revised to "Simulation-aided pressure dependence study of the vWCPC counting efficiency at different operating temperatures"

Line 217: add information for which particle size. Why did you choose 100 nm and not 15 or 25nm in diameter here?

Response: we revised in line 368 to add 100 nm and added one more sentence in line 367-368. We also tested aerosol particles with other diameters, and they showed similar counting efficiency trend changes as Fig 6. When we observed the counting efficiency decreases, we didn't know how much change the supersaturation profile inside of the instruments might have. Therefore, we choose 100 nm to ensure the aerosol particle activation is not affected by the supersaturation decreases.

Line 234: "low pressure conditions" – please be more precise

Response: we revised line 392.

Line 235: the authors mention "saturation ratio over 1.3 and particles larger than 15 nm" however this is not what is presented in these figures (4,5,6). Please review the sentence/figures.

Response: we revised in line 384- 385 and line 390.

I am curious to know whether you tried any pressure setting below 500hPa in your study? If yes, what was the lowest pressure and what were the results?

Response: the lowest setting we tried is 300 hPa. Above 500 hPa CPC, the performances are consistent among the three vWCPCs we tested. The two of three worked well to 300 hPa with the moderate setting changed to 27 C, but not the first loaner one, which I couldn't further evaluate after returning the loaner.

Line 241: although it may be obvious to those who worked with CPCs, please briefly explain what the pulse height is

Response: we revised in line 400 and added "The reported pulse height by a vWCPC indicates the fraction of the particle population generating an acceptably high pulse."

Line 243-244: add reference to the figure when describing the result

Response: we revised to add Fig 7(a) in line 403.

Line 252: please add ref to the fig in supplemental material

Response: we added the reference to the fig in supplemental material in line 407 - 412.

Fig.7 Y-axis label. Please change to "Counting efficiency" for consistency

Response: Thank you very much for catching that. We revised Fig. 7.

Fig.S5: figure legends could be improved, currently displayed weird

Response: we revised all the figures in the supplemental doc.

Section: 3.4. "Chemical composition" – the authors refer to the particle material? Also this section could be made more concise.

Response: we revised it to "Effect of particle chemical composition on the vWCPC counting efficiency". We also revised this section to make it more concise.

Line 267-260: add reference to fig when describing these results.

Response: we added "as shown in Fig. 8" in line 445.

Line 270: what kind of analysis?

Response: we removed this sentence because the simplified condensation effects analysis in the supplemental section didn't fully explain the chemical effect.

Line 268 and 271: how to understand that counting efficiency statements "similar" and "affected" Please review this subsection.

Response: we revised the sentence in line 445: "we get the counting efficiencies close to 1 for PSL, humic acid and AS particles, as shown in Fig. 8.".

Line 272: you mention sucrose and humic acid as particle material used. Please discuss why and what these two represent.

Response: we revised line 441-443: "We choose two types of 100 nm aerosol particles: water-insoluble particles, such as oleic acid, humic acid particles and PSL, and highly hydrophilic ammonium sulfate and sucrose particles."

Wouldn't you expect that at 100 nm particle size these all particle material would be at 100% counting efficiency at ~900-1000 hPa? Why this is not the case e.g. for sucrose?

Response: This observation is consistent with the previous study (Hering et al., 2017). One possible explanation is that the chemical similarity between the seed particle material and the working fluid also affects the detection efficiency of vWCPC (Wlasits et al., 2020).

Fig. 8. Please add information in the caption on the size of these particles and their material.

Response: we revised the caption to "Fig. 8, CPC 3789 counting efficiency at different operating pressure with four different types of 100 nm aerosol particles (PSL, humic acid, AS, and sucrose), when the temperature conditions are Tcond = 27 ℃ and Tini = 59 ℃. "

Line 285-286: butanol-based CPC? Which model from which study? Please add a reference or additional information.

Response: we revised in line 490-492: "For the butanol-based CPC, such as CPC (TSI , 7610), the CPC cut-off size was strongly influenced by the temperature difference between the saturator and condenser (Hermann and Wiedensohler, 2001; Kangasluoma and Attoui, 2019)."

Line 287: please add ref to the figure.

Response: we revised in line 492-493: "We observed that this trend held well for the vWCPC using AS particles, as shown in Fig. 9."

Fig.9: In legend you state "30C TSI". Please specify for which particle material and pressure settings these results were obtained. Also why there is a difference in the slope between the results indicated as TSI and of this study? Do you have data points you could add for 30 C to see if your data agrees with the one referenced as TSI 30C?

Response: we revised the caption to "Fig. 9, CPC 3789 counting efficiency changes as a function of the different operating pressures (500, 700, and 910 hPa) using AS particles, when the initiator temperature is 59 ℃, and the moderator temperature is 10 ℃, at two different conditioner temperatures (a) Tcond = 24, (b) Tcond = 27 ℃." We also added one more sentence about TSI 30 C in line 498-500. "Note that the counting efficiency curve from TSI at 30 ℃ was derived and fitted using the AS particle classified by a custom-made Vienna-type different mobility analyzer(Wlasits et al., 2020). "

The authors may consider adding a summary table in supplemental material that presents various temperature and pressure settings investigated, and resulting cut off sizes for certain particle material used.

Response: we revised section 3.5 to include particle material used in the cut-off size characterization. In legends of Fig 9 (a) and 9(b), we included the temperatures and pressures for the characterization.

It would be interesting to see if vWCPC flow rate (and so the instrument response) is influenced by the changing pressure. This CPC uses an internal pump, is that correct? What was the flow rate at various pressure settings? The authors may want to add a plot in the supplemental material.

Response: Yes, the CPC uses an internal pump and a critical orifice to control the 0.3 lpm volumetric flow. We monitored the critical pressure ratio, which is derived by dividing the absolute pressure downstream of the orifice by the absolute pressure upstream of the orifice. This value was maintained below 0.528 for all the testing reported in this manuscript.

Section 4. Conclusion: I suggest to revise this section. Currently some detailed information is missing and not all information that is given is clear. I would be interested to see what is the meaning of these results, and what's the outlook for operating the vWCPC on the aircraft? Do the authors have any recommendations? If yes, what would the optimal setting? Any suggestions for studying the performance of this CPC under 500 hPa? Is such study planned? Little is said about the advantage of the WCPC over other CPCs, and how these results compare to results from other studies. Any limitations or benefits over other studies could be mentioned too.

Response: we revised the conclusion section.

Line 301: "was modified to report environmental pressure"? Please review.

Response: we revised to "inlet operating pressure" in line 519.

REFERENCES:

Williamson, C., Kupc, A., Wilson, J., Gesler, D. W., Reeves, J. M., Erdesz, F., McLaughlin, R., and Brock, C. A.: Fast time response measurements of particle size distributions in the 3–60 nm size range with the nucleation mode aerosol size spectrometer, Atmos. Meas. Tech., 11, 3491–3509, https://doi.org/10.5194/amt-11-3491-2018, 2018.