

## General comments

This paper reports some good work to characterize a commercial water-based CPC, designed for operation near sea level, at reduced pressures, and furthermore that such operation is possible with only minor modification of the instrument. This capability is important for capturing the vertical profile of aerosol in airborne research, and water is a far safer alternative to the traditional butanol working fluid. The measurements are backed up with a modelling study which also helps explain the CPC response, and limitations therein, to pressure changes. I provisionally recommend this manuscript for publication pending changes described below.

The manuscript should have been more carefully proofread prior to submission. Although a number of syntax and typo issues are noted below, all authors are strongly encouraged to have another go at careful proofreading as part of their response to reviews.

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**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 corresponds to the change-tracked version.**

## Specific comments

Why choose 500 mb as the lower pressure limit? Research aircraft reach sub-100 mb and balloons even lower pressures. The graphs may provide the answer, but some statement about why you didn't investigate lower pressure ought to be included, possibly in the introduction. Especially if lower pressure was attempted unsuccessfully, include a few words about what was tried and the outcome.

**Response: we revised the instruction section in line 109-112. "For the pressure condition lower than 500 hPa, the current simulation was highly nonlinear and the returned solution fails to converge. In addition, we observed inconsistent behavior in one of three vWCPC we tested. Thus, this manuscript focused on the measurements and modeling that were done over the pressure range from 500 hPa to 1000 hPa."**

Abstract: should give the pressure range investigated instead of 'low pressure conditions'

**Response: we revised in line 15-16 to add the pressure range.**

Line 29: The statement about detecting sub-100 nm particles isn't strictly correct, since optical scatter detection is possible down to ~50-60 nm (UHSAS, DMT).

**Response: we revised the sentence to “sub-50 nm”**

Please make your use of 'vWCPC', 'wCPC', etc. consistent throughout.

**Response: we revised wCPC to vWCPC.**

Lines 120-121

Equalizing diffusion losses by matching flows also requires matched tube lengths. Please indicate whether this was the case in your setup. Also this apparently contradicts the previous section which said two different flows were used.

**Response: we revised line 146-147 to explain that we focused on 0.6 lpm aerosol inlet flow. In addition, we also revised line 173-174 “Both CPC 3789 and A.E. were run at 0.6 lpm inlet flow with matched tubing lengths to ensure equal diffusive particle loss in the aerosol pathway.”**

Lines 137-138: To make it clear you are describing other work here, suggest starting the 2nd sentence this way: "They first computed the temperature and humidity profiles were using..." The next sentence describing the Hering et al. configuration doesn't seem to add anything to this paper and could be omitted.

**Response: we revised section 2.3 accordingly.**

Lines 162-163: What's the sample rate? How many samples during each 5-min. run, approximately? Otherwise we can't make sense of any standard deviations.

**Response: The sampling rate is 1 Hz (added to line 290). Thus, during each 5 min, we collected around 300 data points.**

Line 183: The title of section 3.2 doesn't reflect the combination of model and observation within it.

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

Line 198: '...one 8 nm seed particle grew to a smaller size...' Unclear what is meant here - please rewrite. Also change 'no matter' to 'whether'

**Response: Sorry for the misleading, it is “... one 8 nm seed particle grew to a smaller size”.**

Lines 234-235: It's not at all clear how the observations of 100 nm particles in Fig. 6 inform the behavior of particles at smaller sizes down to 15 nm.

**Response: we revised in line 384-385 and added Fig S3, “Although we presented data with 100 nm particles in Fig. 6, we observed a similar trend with particles down to 15 nm (Fig. S3).” Then, we also revised in line 390-392, “Combining the observations from Fig 6 and Fig S3 and the simulation in Fig. 4 and 5, when the simulated saturation is over 1.3, the counting efficiency maintained close to 1 for aerosol particles larger than 8 nm under low-pressure conditions (500 – 920 hPa).”**

Sect. 3.3:

Lines 241-242: Does this mean it does not count pulses that are below some trigger threshold? Insert 'of maximum' after '90%'

**Response: we revised in line 400-402,” The reported pulse height by a vWCPC indicates the fraction of the particle population generating an acceptably high pulse. The manufacture's manual described the pulse height being above 90% for moderate concentrations (~10-5,000 cm<sup>-3</sup>).”**

Lines 245-246: Suggest rewriting this sentence: 'Meanwhile, for 100 nm particles at 500 hPa, the threshold concentration for a 10% reduction in counting efficiency was about...'

**Response: we revised accordingly in line 404-405.**

Lines 249-251: This is an important point that is not easy to see, and isn't shown in Fig. 7. Suggest pointing to the supplement figure: 'Additionally, Fig. S5(b) shows there is no significant...'

**Response: we revised accordingly in line 409.**

Also: change '...simulation estimated 10% reduction of s and Dp happened...' to 'simulated 10% reduction of s and Dp...'

**Response: we revised accordingly in line 411.**

Sect. 3.5 & Conclusions:

Should include a statement about the cut-off being less sharp than for the TSI standard settings, as the price for operation over a much wider pressure range. This can be important in the presence of a large ultra-fine particle mode.

**Response: we added in line 498-505, “Note that the counting efficiency curve from TSI at 30 °C was derived and fitted using the AS particle classified by a custom-made Vienna-type different mobility analyzer under a standard operation condition (Wlasits et al., 2020). As a result of operation over a much wider pressure range, the cut-off curve derived by this study is less sharp than for the TSI standard settings. ”**

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Technical corrections, by line or label:

53 comma after 'system'

**Response: added in line 82.**

61 strike 'her'

**Response: removed 'her' in line 90.**

67 comma after 'initiator'

**Response: added in line 112.**

68 change ')' after 2017 to a semicolon

**Response: changed in line 113.**

85 change 'guided' to 'guide'

**Response: changed in line 132.**

101 change 'positive pressure difference' to 'positive difference'

**Response: change in line 157.**

104-106

Suggest recasting this sentence to 'Thirdly, we added pressure transducers (Baratron 722B, MKS Instruments, Inc., Andover, MA, USA) to the vWCPC inlet and exhaust lines.'

**Response: changed in line 160-161.**

Fig. 1 Please label at least one of the filters in the figure, or identify in the caption.

**Response: we labeled the HEPA filter connected to the flow buffer.**

150 change '...which shows that the flow rate varied...' to 'which shows that when the flow rate increased...'

**Response: changed in line 274.**

158 change 'maintained 2~4' to 'maintained in the range 2-4'

**Response: changed in line 286.**

Fig. 3 Please state in the caption that the configuration is TSI's standard.

**Response: stated in line 313.**

188 Change both instances of 'was' to 'is'

**Response: changed in line 338.**

196 Strike the comma after 'both'

**Response: removed the comma in line 345.**

Fig. 4 It would be helpful to separate the bunched contour labels.

**Response: In the publication version, we can make the figure larger to separate the labels.**

Caption: change 'temperature is 59' to 'temperature at 59'

**Response: changed in line 357.**

Fig. 5 caption: change 'temperature is 59' to 'temperature at 59'

**Response: changed in line 364.**

227 change 'imitator' to 'initiator'

**Response: changed in line 382.**

236 change 'than the' to 'than when the'

**Response: change in line 393.**

240 insert 'efficiency' after 'counting'

**Response: inserted in line 399.**

Fig. 7 caption: change ' temperatures were set' to ' temperatures set'

**Response: changed in line 437.**

268 change 'efficacies' to 'efficiencies'

**Response: change in line 445.**

285, 287 change 'was' to 'is'

**Response: changed in line 490.**

Fig. 9: Drop the '25' tick label, both panels

**Response: we updated Fig. 9.**

307 change 'the above phenomena' to 'this behavior'

**Response: the sentence was revised in 525.**

308, 309 'at' is preferable to 'under' because 'under 1000 hPa' might be read as 'less than\_ 1000 hPa, e.g.

**Response: changed in line 526.**

Author contributions: Gregory Lewis and Maynard Havlicek are omitted.

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Supplement

After Eqn. 1 (for  $D_{th}$ ): the expression for  $D_{th}$  at other than STP is missing.

**Response: we assume that the pressure effect on the  $D_{th}$  is negligible.**

After Eqn. 2 (for  $D_{va}$ ): '(0.21 by Steve)' what is this?

**Response: we have removed this additional note.**

Please give a source for the Antoine equation empirical constants.

**Response: added the reference.**

Please define all quantities in the diffusion time expressions. Many are not.

**Response: The diffusion time expressions for simulating the simplified condensation effects were included in the previous publication by Latham and Nenes (2011). We briefed the main equations in the supplement document and added the reference of the diffusion time expressions in line 78-80.**

The primes in Eqn. 6 (for Gamma) appear to be on the wrong characters, and their meaning is not identified.

**Response:  $\Gamma$  is a growth parameter that depends on the droplet size and the water vapor mass transfer coefficient.**

After Eqn. 3 (for  $Le$ ): '...as detailed in the supplement.' This IS the supplement. Do you mean '...as detailed above'?

**Response: changed to “as detailed above”.**

Fig. S2

Main title and y-axis labels need attention. May just be PDF rendering problems, but in my copy the RH unit reads '(l)', and the title repeats 'Relative humidity (l)' three times.

Caption: change 'calculated at the' to 'calculated along the'.

**Response: we revised Fig. S2 and caption.**

After Eqn. 4 (for  $s$ ): 'and assuming  $dT/dz=G$ ' should just be ' $G=dT/dz$ '

**Response: changed.**

Following paragraph: change 'hence lower the droplet size' to 'hence a lower droplet size'

**Response: changed**

After Eqn. 7 (for  $C\text{-dot}$ ): change 'assume' to 'write'

**Response: changed**

After Eqn. 9 (for  $D_p/D_{p0}$ ): change 'set to equal' to 'set equal'

**Response: removed “to”**

Following sentence: remove ', which' after 0.01

**Response: removed “,”**

Next sentence: should be Fig. S3, not 3.

**Response: changed to Fig. S4.**

Fig. S3

X- and Y-axis labels, and the legend, need attention. Subscripts and superscripts are displaced from other characters. Again, this could just be a PDF rendering problem.

Please narrow the legend box to avoid clipping the traces if possible.

Are all the 'exit' subscripts necessary? Maybe strike them and instead include 'at the initiator exit' somewhere in the caption?

Caption: change 'setting temperatures' to 'temperature settings'

**Response: revised Fig. S4.**

2nd paragraph after Fig. S3, 1st line: change 'function as' to 'are functions of'; and again Fig. S3, not 3.

**Response: changed in line 127**

The accommodation coefficients are discussed here, but don't appear in any expressions. How were they used?

**Response: we added additional information after equation (10).** “Where  $k_a'$  is a modified thermal conductivity described as equation (17.72) by Seitfeld and Pandis (2016).  $D_{v\alpha,p}'$  is a modified mass diffusivity described as equation (17.62) by Seitfeld and Pandis (2016). When calculated the above two modified conductivities, we assume the value of the thermal accommodation coefficient ( $\alpha_T$ ) was set equal to the mass accommodation coefficient ( $\alpha_c$ ) in this simplified analysis.”

Fig. S4 caption

Change 'for the droplet size is 3 mm when the droplet exit the initiator' to 'for a droplet size of 3 um exiting the initiator' (making sure to correct mm to um). Please add a sentence describing the insets.

**Response: we revised the caption.**

Figs. S5, S6



Axis labels and legend text are far too small. Legend superscripts are dramatically separated from their base characters.

**Response: we revised both figures.**

Fig. S5(b)

There are no magenta points on the plot, but they are in the legend (24C,  $N=2e4$ , 20 nm case).

**Response: we revised Fig. S6(b). The previous figure was messed up during the pdf conversion.**

Fig. S5 caption, last sentence: strike 'were' and the following 'with', and correct 'temrperature'.

Fig. S6 caption: change 'temperature is 59' to 'temperature at 59'.

**Response: we revised captions of Fig. S5 and S6.**

Table S1

Asterisk-bullet mismatch for the note; use the same symbol.

**Response: revised.**

References: Seinfeld and Pandis (2016), Lathem and Nenes (2011), Nenes and Seinfeld (2003) are not given anywhere, main or supplement.

**Response: we updated the reference for the supplement.**