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Atmospheric Measurement Techniques
Discussions

Interactive comment on "B3010: A Boosted TSI 3010 CPC for Airborne Studies" *by* David Picard et al.

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article

General comments

We, the authors, would like to thank Anonymous Reviewer # 3 for his/her interest in our work, and for suggesting changes for the sake of clarity and quality of the paper.

Specific comments

1. Figure 1

Reviewer : "Figure 1. The scheme of B3010 should indicate which elements

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have been improved/changed compared to the standard 3010 instrument. The adequate edits tn the modification description should be added in the text."

We reworked figure 1 (instrument diagram) to show the B3010 and the TSI 3010 side by side. It will look much like the figure attached to this reply.

In the paper, the text right bellow Fig. 1 lists the changes we made from the original TSI 3010 model. In a nutshell, it mainly consists in :

- thermally decoupling the condenser from the saturator to allow independent temperature control
- controlling the flow rate (when the internal pump is connected in place of the critical orifice).

The saturator, the condenser and the optics are those from the original TSI 3010.

2. DMA and electrometer

Reviewer : "Provide more details on the DMA (Dynamic mechanical Analyzer) and the reference AEM used"

In the scope of this paper, DMA stands for *"Differential Mobility Analyzer"*. The DMA will be better described in the next version of the paper, section "3.1 Experimental setup". We plan to add the following text :

"The DMA used in this study is called a Hermann type DMA and has been described in details in Kangasluoma et al. 2016. DMAs are operated with 2 flows : Q_a, the aerosol (or sample) flow, and Q_s, a filtered, aerosol-free sheath flow. The size resolution of a DMA is given by the ratio $\frac{Q_a}{Q_s}$.

Typical DMAs are operated at Q_a of 1-4 l/min and Q_s of 5-20 l/min. The Hermann type DMA used in this study is operated at Q_a = 10 l/min and Q_s in the range of 250-

1500 l/min. The much higher $\frac{Q_a}{Q_s}$ ratio is the key to select aerosol particles with high resolution.

A high resolution DMA is needed because the particles used to measure the detection efficiency are in a very narrow size range. With Fig. 3b, we can calculate the resolution of the DMA, defined by the full width at half maximum of the peak (FWHM) over the central size of the peak (Kangasluoma et al. 2016). The FWHM of 0.1 nm over the monomere size 1.47 nm gives a resolution of 0.07 in the conditions of the experiments."

The electrometer used in this study is a Keithley 6517B. This will be mentioned in the paper.

3. Results and discussion

Reviewer : "Why do you see remarkable differences in detection for positively and negatively charged particles?"

This is a well-known phenomenon known as *"sign preference"*. We would like to add the following text to the paper, in section "4.1 Laboratory calibration" :

"We can see in Fig. 4 that the counting efficiency is higher for negative particles, compared to positive particles. This phenomenon is known as "sign preference", and has been observed by a number of studies before us. Already a century ago, Wilson 1897; 1899 reported that more fog is formed in an expansion chamber when negative ions are present compared to the presence of positive ions, and also more fog formation in the presence of bipolar ions compared to no ions at all. Wilson is cited by McMurry 2000. More recent studies (Winkler et al. 2008, Kangasluoma et al. 2013) reported the same thing. Our work is thus in accordance with previous studies."

These additional references will be added in the next version of the paper :

- Wilson, C. T. R. (1897). Condensation of Water Vapour in the Presence of Dust-

Free Air and other Gases. Philosophical Transactions of the Royal Society of London 189:265-307.

- Wilson, C. T. R. (1899). On the condensation nuclei produced in gases by the action of röntgen rays, uranium rays, ultra-violet light, and other agents. Philosophical Transactions of the Royal Society of London 192:403-453.
- McMurry, Peter H. (2000). The History of Condensation Nucleus Counters,Aerosol Science and Technology, 33:4, 297-322
- Winkler, Paul M. (2008). Heterogeneous Nucleation Experiments Bridging the Scale from Molecular Ion Clusters to Nanoparticles. Science 07 Mar 2008, Vol. 319, Issue 5868, pp. 1374-1377, DOI: 10.1126/science.1149034

Reviewer : "How do you measure pressure?"

The absolute pressure sensor is a FirstSensor HDI0611ARY8P3 (600-1100 mbar). The differential pressure sensor is a FirstSensor LDES050UE3S (50 Pa, unidirectional). The flow rate was calibrated with a Drycal Gilibrator bubble volume flow meter for a number of absolute pressures.

The section "2. Design of the B3010" of the paper will contain more details about pressure and flow measurement, with the addition of the following paragraph : *"The absolute pressure is measured by a miniature sensor, connected to the optical chamber with a capillary tube. The pressure intake is centrally located, between the saturator-condenser block and the laminar flow element. Besides, given the low pressure drop in the flow path, the absolute pressure does not change much from the inlet to the laminar flow element. The volume flow rate is calculated from the differential pressure measured by a 50 Pa miniature sensor accross a laminar flow element and compensated for absolute pressure. The volume flow rate is a key measurement, since it is used to calculate the particle number concentration. The concentration C is calculated*

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from the number of particle counts N, accumulated during T_S, at a volume flow rate Q_V : $C = \frac{N}{Q_V \cdot T_S}$"

"Reviewer : "Figures in this section need better descriptions, some error analysis should be added into the text."

Most figures in this section show the detection efficiency of the device under test, with respect to the reference aerosol electrometer.

The detection efficiency E of the CPC is given by the ratio between the particle concentration measured by the CPC, C_{CPC} to the particle concentration given by the aerosol electrometer, C_{AE} for different diameters, signs or ΔT :

$E = \frac{C_{CPC}}{C_{AE}}$.

To calculate the diameter at 50 % efficiency, D_{P50}, we applied an exponential fit to the data from Fig. 9 of the paper :

$E = y_0 - e^{\frac{x_0 - x}{k}}$

Where x is the particle size, and y_0, $x0$ and k are the coefficients of the fit. This type of fit is commonly used by Global Atmospheric Watch aerosol calibration centers (*e.g.* TROPOS, Leipzig, Germany).

Evaluating the inverse fit function at a counting efficiency $E = 0.5$, and knowing the resolution of the DMA, we can tell that $D_{P50} = 2.5 \pm 0.1\ nm$ (see Fig. 1 attached).

We plan to add this to the paper.

Reviewer : "Also more discussion real measurements and comparison between B3010 and 3025 should be more detailed. Do you observe drift in the performance of the sensor in the course of the tests, which Fig. 10 suggest? If so why?"

Indeed, in the first submitted version, the measurements used to make Fig. 10 were not correct. A closer look at the data actually showed a drift of the B3010. It was probably caused by a too high room temperature (higher that 30 degC), that must have caused the condenser temperature of the B3010 to stray from the setpoint, thus reducing the counting efficiency.

As a consequence, we ran another ambient air test at room temperature of 20 degC. In addition to the TSI 3025, we also compare the B3010 to a TSI 3010, sampling every second, and using 1-minute averages for the plots. The total counting efficiency of the B3010 vs. that of the TSI 3025 is now in accordance with the rest of the article. In Fig. 8, for example, the efficiency of the B3010 is higher than that of the TSI 3025. This is also the case in this ambient test, when concentrations bellow $10,000\ \#/cm^3$ are considered.

In the figures attached to this reply, we call "low concentration" conditions the time period when the concentration was bellow $10,000\ \#/cm^3$. In Fig. 2 attached (3 CPCs time series), we can see that the B3010 displays a higher concentration than the TSI 3025, which is itself higher than the TSI 3010. We plot in Fig. 3 attached three particle size bins, obtained by the difference of the concentrations reported by CPCs pairs :

- small : B3010 minus TSI 3025, 2.5-3.0 nm
- medium : TSI 3025 minus TSI 3010, 3-10 nm
- large : TSI 3010, > 10 nm

One can see that particles in the range 2.5-3.0 nm account for about a third of the total particle concentration.

We will update the ambient air experiment in the next version of the paper.