Causes of Concentration Differences Between a Scanning Mobility Particle Sizer and a Condensation Particle Counter

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Abstract:

Accurate aerosol concentration measurement is important in many application of aerosol science. Here we compare aerosol concentration measurements of classified NaCl aerosol in the size range of 20 to 80 nm (diameter) between a scanning mobility particle sizer (SMPS) and a condensation particle counter (CPC). The SMPS systematically measured higher concentration than the CPC, with the difference increasing with decreasing size. Experiments suggests several causes for the discrepancy. First, the factory calibration of the SMPS impactor flow was incorrect for the study site at 780 mb. Second, the neutralizer used in the SMPS was inefficient in bringing the classified aerosol to charge equilibrium and third, there was significant losses of charged aerosol within the CPC. The comparisons were improved with proper impactor flow calibration and proper charge neutralization of the classified aerosol before measurement by the SMPS and CPC. The results of this study point to the importance of proper conditioning of aerosol below about 100 nm for measurement with SMPS and condensation-based particle counters.

Introduction:

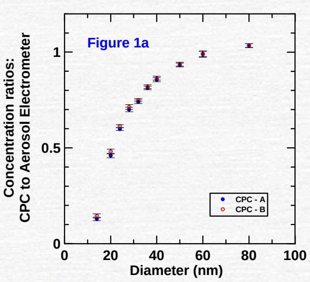
Accurate in situ determination of aerosol size distributions requires instruments which have been calibrated for both their size and number concentration measurements. The issue of calibration with respect to number concentration has not been well addressed. For aerosol number concentration it is common practice to use a CPC as such a reference and when size is required a SMPS is used. Here the two instruments are compared and the results are somewhat troubling. For particles below 100nm, the SMPS concentrations are systematically higher than the CPC concentration with the concentration difference increasing with decreasing size. The instruments compared were a TSI SMPS (model 3936L10) and a TSI CPC (model 3010). The CPC in the SMPS was also a model 3010 and tuned to match the external CPC in stand alone test. The results from several experiments indicated both obvious and subtle causes for the discrepancies.

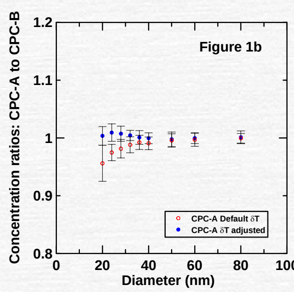
Instrumentation:

A TSI monodisperse aerosol generation system (model 3940) was used to generate the NaCl test aerosol. An aerosol electrometer was used for CPC calibration. A TSI 3077 neutralizer (2 mCi ^{85}Kr source) and an Aerosol Dynamics Inc., neutralizer (ADI) (2 mCi ^{210}Po source) were used in different experimental configurations.

Comparison of Two CPCs:

To ensure comparable measurements for the two CPCs they were tested against an aerosol electrometer for a range of sizes of NaCl aerosol. The resulting counting efficiencies of the two CPCs using the factory default temperature setting of $\delta T=17°C$ are shown in Figure 1a. δT on CPC-A was increased by 0.3 °C which resulted in better agreement between the two CPCs as shown in Figure 1b.





RESULTS:

SMPS and CPC Comparisons:

The experimental configurations for the SMPS and CPC comparisons are shown in Figure 2. The first comparison excluded the ADI ^{210}Po neutralizer (shown encased within dotted rectangle) but included the the TSI 3077 ^{85}Kr neutralizer as in a standard configuration and operated at nominal sheath flow of 6 l/min. and aerosol flow of 0.6 l/min.

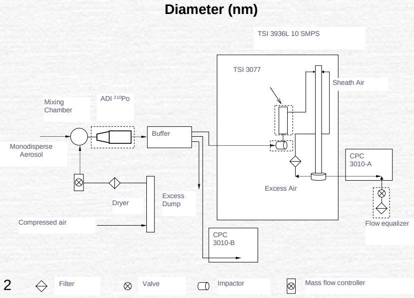
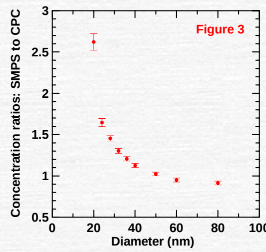
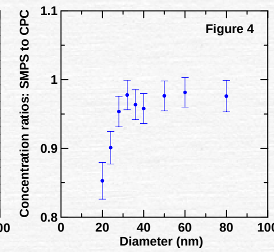


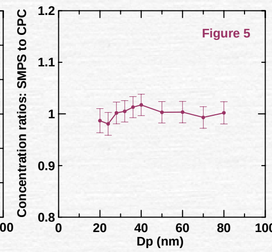
Figure 2

Using factory calibrated aerosol flow through the impactor, the SMPS concentration for 50-80 nm particles are ~20% higher than CPC concentrations, with this difference increasing for particles less than 50 nm. The aerosol flow displayed on the SMPS panel was found to be in error of ~17% due to pressure difference between study site and manufacturer's site. This point is important to note when the impactor flow is used for investigation at pressure different from the manufacturer's.

The impactor flow was recalibrated for ambient pressure (780 mb) at the study site and the experiment performed again. The comparison improved but the SMPS still measured higher than the CPC for particles below 40 nm, the difference increasing with decreasing size as seen on Figure 3.

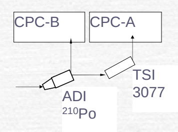


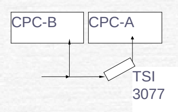




The TSI 3077 neutralizer was replaced with an ADI neutralizer but placed ahead of the buffer chamber so that both the SMPS and the CPC measured particles in charge equilibrium. This resulted in a much better agreement as seen in Figure 4, although some discrepancy still existed for particles below 25 nm. Removing the impactor and flow equalizer from the SMPS and operating at a sheath flow of 10.0 l/min. and aerosol flow of 1.0 l/min. further improved the comparison as seen in Figure 5. The increased flow through the SMPS would reduce diffusional loss and may explain the improvement seen for the smaller sizes.

Figure 6





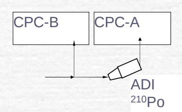
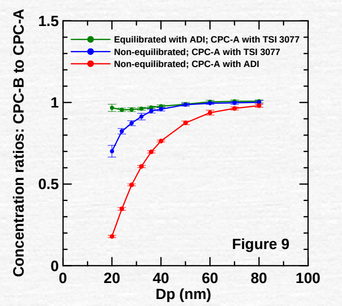


Figure 7 Figure 8



CPC Comparison of Charge Neutralized and Non-Neutralized Aerosol:

First classified aerosol, charge neutralized by passing it through the ADI neutralizer was routed to CPC-A from the SMPS, preceded by a TSI 3077 and to CPC-B, the external CPC (Figure 6). In a second experiment, the same flow configuration was used, but with the ADI neutralizer removed (Figure 7). Finally, the flow configuration of the second experiment was modified by replacing the TSI 3077 with the ADI neutralizer (Figure 8). The results (Figure 9) for the first comparison indicated good agreement between the two CPCs for the neutralized aerosol but poor agreement was found for the second and third comparisons. Since particle loss in the last two comparisons is expected to be the same up to the point where aerosol enters CPC-B and the charge neutralizer on CPC-A, any differences must result from differences in aerosol loss within the two CPCs for charge neutralized and non-neutralized aerosol. Differences between CPC-B and CPC-A for the different neutralizers indicate changes in the number of particles counted by CPC-A. Assuming the loss in CPC-B is due to charged aerosol, CPC-A measurement will increase as the efficiency of the neutralizer increases. Results in Figure 9 suggest that ADI neutralizer is more efficient than the TSI 3077 neutralizer. Particle free air passed through the ADI neutralizer and fed to both CPCs indicated no particles were measured, thereby eliminating the possibility that ion-induced nucleation may be occurring in the CPCs.

The significant loss of classified particles in the CPC-3010 is disturbing as many calibrations of aerosol instruments are performed with classified particles and referenced to a CPC without being neutralized.

Conclusion:

Discrepancies between the SMPS and CPC concentration of size classified aerosol stem from both inefficient charge neutralization by the TSI 3077, giving an enhanced SMPS concentration, and from loss of charged aerosol in the CPC. Efficient neutralization of classified aerosol to charge equilibrium reduced the SMPS concentration and increased the CPC concentration by minimizing losses in the CPC, giving significantly better agreement between the two instruments.

For more details see Aerosol Sci. Technol., 37, 916-923, 2003

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