Design and calibration of non-sheathed butanol CPC sensitive to 1 nm particles

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Introduction

At the global scale, modeling tools have shown that new particle formation (NPF) by nucleation and growth can significantly contribute to the total number concentrations of aerosol particles and consequently to the number of cloud condensation nuclei (Spracklen et al. 2006). In particular, nucleation is expected to be a major contributor to the total particle number concentration *at higher altitudes* (in the upper troposphere) (Merikanto et a. 2009), where clouds mostly form. With the development of instruments detecting particles at the nanometer scale, NPF events have been observed in a growing number of environments[4], and recently detected at high altitudes with a high frequency (Venzac et al., 2008; Boulon et al. 2010, 2011 ; Rose et al. 2015). However, understanding the mechanisms behind the nucleation process requires that particles in the sub 3 nm range (cluster particles) be detected. But until only a few years ago, before instruments that "pre-grow" particles upstream of a regular CPC (*e.g.* Airmodus' Particle Size Magnifier – PSM) were released, only natural cluster ions could be detected in the natural environment.

We present here the recent development of a nano-CPC capable of detecting neutral clusters in low pressure environments such as high altitude stations and airborne platforms, while keeping the design simple.

Butanol nano-CPC design

Commercial fine condensation particle counters in boosted conditions (50°C for the saturator temperature and 10°C for the condenser temperature) have recently demonstrated their ability to detect particles in the sub 3 nm range (Kangasluoma et al., 2015) with butanol as the working fluid. The main benefit of using butanol is that the final droplets are large enough to be directly detected by an optical counter, which is not the case of diethylene glycol used in PSMs. PSMs thus need a companion CPC to grow particle further, and detect them.

This high detection efficiency is obtained when the temperature difference between the saturator (Ts) and the condenser (Ts) is increased from 17°C (non boosted conditions) to 40°C (boosted conditions). The temperature setpoints of the TSI 3772 and Airmodus A20 used in Kangasluoma's study are limited to 50°C. The goal of our development is to build a similar CPC based on the TSI 3010 model with a new and independent heating and cooling system. This allows more flexibility to adjust temperatures and flow rate. The original flow control with a critical orifice and a heavy pump is replaced by a laminar flowmeter and a miniature rotary vane pump. The saturator temperature (Ts), the condenser temperature (Tc) and the flow rate of the instrument are totally controlled by the user.

Calibration

The detection efficiency is measured with an aerosol electrometer (Faraday cage + Keithley electrometer) with standards sub 2 nm ions produced with electrospray classified by a high resolution DMA (Attoui type) for different temperature differences (ΔT) and flowrates. Careful attention has been paid in selecting the thermoelectric coolers (Peltier elements) and designing their power supply, in order to achieve a lower saturator temperature than in most commercial CPCs (typically 10°C). Low condenser temperature helps to keep a high ΔT at relatively low saturator temperature in order to decrease evaporation losses of volatile particles and thermal diffusion losses in the saturator. The saturator and condenser are thoroughly insulated to minimize heat losses, and hence, power consumption. The CPC is designed to be powered by a 28VDC power source, making the instrument lighter and easier to integrate in research aircrafts.

Detection efficiency will be characterized with hydrophobic particles produced by evaporation-condensation of ammonium sulfate with an oven, as well as with singly charged positive and negative, hydrophobic particles of tungsten oxides and nickel chromium oxides, produced by a hot wire generator, down to 1 nm.

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