Effective density measurements of different fresh soot types

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Introduction

In the atmosphere, black carbon is known to reduce visibility and affect the global radiation budget. A recent study has estimated the direct radiative forcing due to present-day black carbon emissions to be in the range from +0.17 W/m² to +1.48 W/m², with a certainty of 90 % (Bond et al., 2013). In order to better understand the role of black carbon in the atmosphere, a detailed characterization of freshly emitted particles and their subsequent ageing processes, involving coating due to condensation of secondary material, and possible restructuring of soot agglomerates, is needed. The knowledge of the particles' density is crucial because it is directly influenced by restructuring of soot particles.

Herein, we present size, density and mass distributions of freshly produced soot particles from several sources. The particles are characterized using a Differential Mobility Sizer (DMA) system and a Centrifugal Particle Mass Analyzer (CPMA), in series.

Another reason for conducting these measurements are mass-based thresholds used in air quality monitoring. Since the CPMA classifies particles according to their mass-to-charge ratio (Olfert & Collings, 2005) the mass distribution measurements can be a powerful application to determine the mass-based net output from any source. The results could then be compared with values obtained from currently used instruments.

Experimental

The actual experiments were performed in our laboratory at ETHZ. Four types of soot particles were generated. In more detail, two types using a Combustion Aerosol Standard (CAST) burner (fuel-rich (1) and fuel-lean (2)), one type (3) from a PALAS GFG aerosol generator and a (4) carbon black (Cabot Regal Black). Soot type 1, 2 and 3 are especially marked as surrogates for diesel soot by the manufacturers. In addition, soot particles from aircraft engine exhaust were investigated at the airport in Zurich during the Aviation Particle Regulatory Instrumentation Demonstration Experiments (A-PRIDE) campaign in November 2012. Here, sampling was performed directly behind the engine.

The freshly generated soot particles are first charge equilibrated to account for multiple charging and selected according to their mobility size (d_m) by a DMA. The monodisperse flow then enters the CPMA that records the mass distribution by scanning over the relevant mass range. A condensation particle counter counts the corresponding particle number concentration.

Results

Fig. 1 exemplarily depicts the effective density (ρ_{eff}) of soot from aircraft engine exhaust for different selected d_m measured during A-PRIDE. This can be mathematically derived by using the fractal relationship between the mass and the mobility size and the definition of the effective density. As can be seen, the effective density decreases with increasing mobility diameter. This effect will be discussed in detail for all datasets.

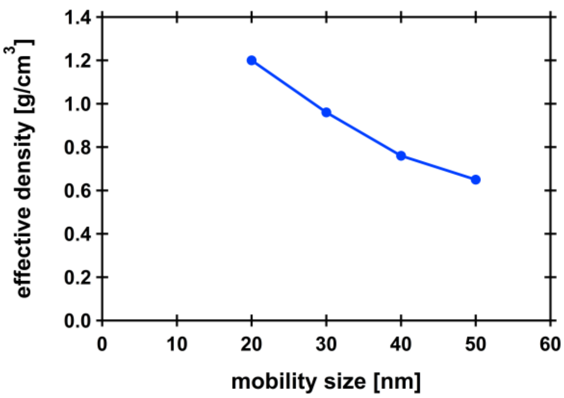

Fig. 1 Effective density of aircraft engine exhaust particles

Furthermore, we will compare our data to those from Gysel et al., 2012, who used an Aerosol Particle Mass analyser (APM) based on a very similar working principle as the CPMA.

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