Links Between Two Different Types Spectra of Charged Nanometer Aerosol Particles

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Abstract. We measured continuously the electrical mobility distribution of small (<1.5 nm in diameter) one-second-aged air ions with our Small Air Ion Spectrometer in urban area, Estonia, in the centre of Tartu since 2007. Simultaneously, we measured the mobility distributions of natural air ions (0.42–7.4 nm in diameter) with the Balanced Scanning Mobility Analyzer. In this work we employ these data to establish certain links between the concurrent spectra of two types, especially for days with new particles formation events. The results show that some events can be due to enhanced concentrations of certain trace gases, especially in case of positive ions.

Key Words: Atmospheric aerosols; clusters, nucleation burst events, air ions

INTRODUCTION

During recent years, the formation and growth of nanometer-sized atmospheric aerosol particles have been studied by several ways because of the crucial impact of aerosols on the radiation balance and thereby on the climate of Earth, but the mechanisms which control the stages of aerosol formation are still not completely understood.¹,²,³ Intermediate ion burst events are considered a part of a substantial channel to new aerosol particles. Because of that, several details of the events have been thoroughly studied. As a result, classification of the events, as well the processes, which control some of the classes, have been proposed.⁴,⁵

In this work we try to apply a new approach to study the intermediate ion concentration burst events. We use a comparative study of charged nanometer aerosol particles size distributions, measured by the BSMA (Balanced Scanning Mobility Analyzer),⁶ and the distributions of about one second-aged small air ions, measured by the KAIS (a special kind Small Air Ion Spectrometer) with internal corona ionizer for ion generation.⁷ The first-step goal is to find out several correlations within the shapes of the spectra. KAIS spectra, like the ones of many ion mobility spectrometers (IMS), are very sensitive to particular trace gases.⁸ Therefore, if certain burst events (measured by the BSMA) tend to occur concurrently with certain classes of KAIS spectra, there can be dominant trace gases, which control these bursts.

Here, we report the results derived from the spectra obtained during January, February and March 2008. During that period, according to the BSMA data, there were two strong bursts with banana-type spectra evolution,⁴ and about ten moderate bursts events.
METHODS

The continuous measurements of air ion size and mobility distribution in urban area were carried out by instruments placed on the roof of the Institute of Physics (ca 70 m asl, ca 20 m from the ground level), in the centre of Tartu, Estonia. BSMA (Balanced Scanning Mobility Analyzer, developed by AIREL Ltd., Estonia) is an instrument for the measurements of positive and negative naturally charged air ion mobility distributions in the range of 0.032–3.2 cm$^2$V$^{-1}$s$^{-1}$ (diameter range 0.4–7.4 nm).$^{6,9}$

KAIS is a unique small air ion mobility spectrometer, originally developed at the University of Tartu.$^{7}$ The improved version of it can be employed for continuous field measurements.$^{8}$ The device uses an extra corona ionizer at inlet and can record the ion spectra within the mobility range from 0.6 to 2.6 cm$^2$V$^{-1}$s$^{-1}$. The recorded new ions are about one second old. The whole spectrum contains 116 points, unlike BSMA, which spectrum contains 16 points.

Both the KAIS and BSMA use the scanning voltage to record the ion electrical mobility spectrum. The devices measured the ions in the natural air, operated at atmospheric pressure and at the temperature of the surrounding environment. The total time to record a raw spectrum is about 1 minute, after preprocessing the BSMA records the 10 minute-average spectra, and KAIS records spectra every 5 minutes. For data analysis we used about 10000 BSMA spectra and about 20000 KAIS spectra, measured during January-March 2008. To find out the concurrent classes of interest, we firstly classified both the KAIS and BSMA spectra according to the mathematical similarity of their shapes. We obtained about 15 classes, some of the classes occur frequently and some do not. Then, we picked up the BSMA classes, which imply to burst events, and looked for the concurrent KAIS classes. The results are presented in the next section.

RESULTS

Figures 1 and 3 depict the average spectra of selected BSMA ion classes, both the common classes (which occur most frequently), and some of the classes, which imply to the burst events (with percentage from the total number of spectra). Figures 2 and 4 depict the average spectra of selected KAIS ion classes. The figures contain both the common classes and the classes, which appear concurrently with certain BSMA classes, as detailed below.

The common BSMA positive ion spectra show no burst (Fig. 1, common classes). The classes A, B and C can be regarded as different examples of the nucleation burst spectra classes.$^{5}$ All of these classes occur concurrently with the KAIS spectra classes A, B and C, which all shapes are close to each other, and which all are remarkably different from the common KAIS spectra (Fig. 2). As a rule, a quite sharp KAIS spectrum corresponds to one trace gas with exceptionally high concentration. As a conclusion, the positive ion nucleation burst classes, depicted in Fig. 1, can be controlled by few trace gases.

The BSMA negative ion classes A and B can be regarded as an outcome of burst events of several types, the class C comes from the spectra with exceptionally low ion concentrations (Fig. 3).
Figures 1 (top), 2 (middle), and 3 (bottom). Average mobility spectra of selected positive and negative ion classes; cases A, B, C can correspond to nucleation burst events.
Figure 4. Average mobility spectra of selected KAIS negative ion classes.

Unlike the positive ion case, there is no particular KAIS spectra class which frequently occurs concurrently with the BSMA classes A and B. On the contrary, KAIS classes A, B, C occur with the BSMA class C (Fig. 4). As a conclusion, these first results show that, in certain cases, it is possible to connect the burst events with the KAIS spectra of particular shape, which implies to certain trace gases controlling these events.

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References