Interactive comment on “Intercomparison of air ion spectrometers: a basis for data interpretation”

by S. Gagné et al.
Anonymous Referee #2
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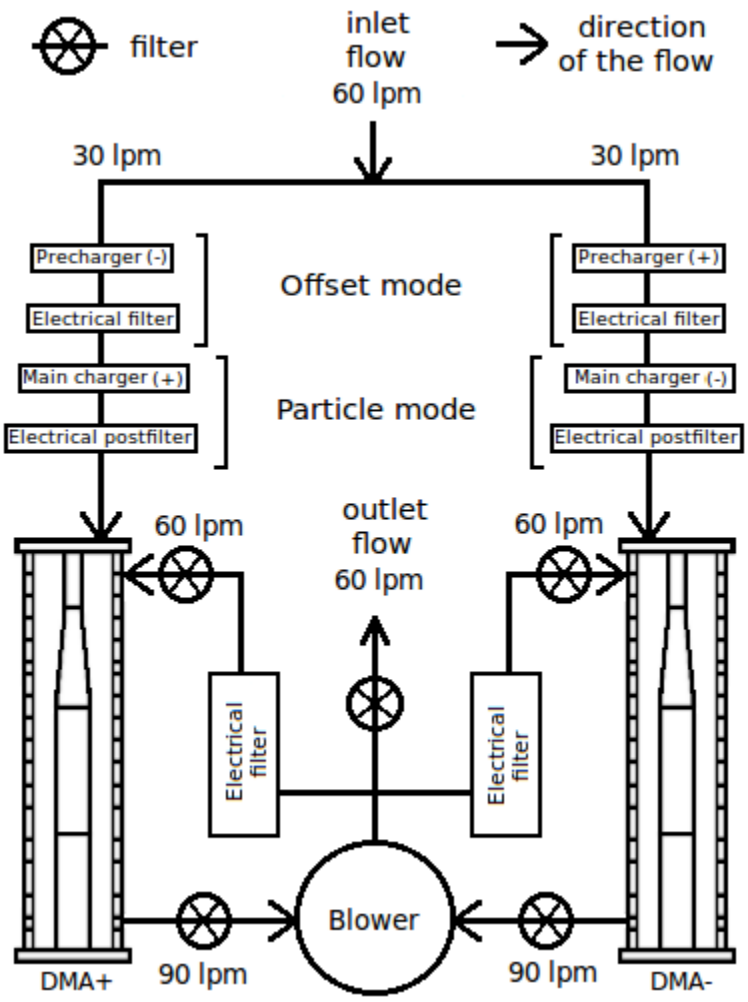
This paper presents an intercomparison of several different types of air ion spectrometer from the Finnish/Estonian school. The experiments are detailed, and make use of reference instruments, mobility standards and comparisons between the individual instruments, all carried out in a number of different environments. The differences between the different instruments are explained, and a new particle formation event is used as an example of their consistent behavior.

First of all, the authors would like to thank the referees for their constructive comments. We believe that the changes generated by these comments make the manuscript easier to understand.

This is a careful and thorough piece of experimental work which is completely sound, but could be presented more clearly to non-specialist readers, or those who are perhaps more users of ion spectrometers than developers of them. The major omission is any sort of diagram of the equipment used. The inlets and air flow are mentioned as a key difference between the instruments, and it would help to see schematics of each of the instruments compared, perhaps including basic layout and electronics.

We realize that such a schematic figure was missing. It indeed improves the readability of the manuscript a great deal. We have added a schematic figure of the NAIS (Fig. 1). The AIS is the same instrument excluding the “particle mode” module (main charger and electrical post-filter). We did not, however, include a new figure for the ANAIS because it is much like the NAIS and the changes are described in section 2.3. We also added a figure describing the experimental setups at the demand of Anonymous Referee #1 (Fig. 2).



For such a detailed piece of experimental work, the abstract and text are both lacking quantitative comparisons. The text uses words like "agreed", but it would be more helpful for the authors to state the variability range of the different instruments. For example, in one place where the instruments "agreed fairly well", referring to figure 4a, there was an order of magnitude difference between the maximum and minimum values recorded. These measurements are known to be difficult, and the results obtained are impressive, so it is best to be absolutely clear about the disagreements that are occasionally seen.

*The sentence "*The latter agreed better with reference instruments.*" in the abstract was replaced by "For example, the AISs agreed with the BSMA within 11% and 28% for negative and positive ion concentration respectively, whereas the NAISs agreed within 23% and 29%."*

Regarding the text accompanying Fig 4a (now Fig. 6a), we changed it to be more descriptive (changes in bold font):
"The concentrations ***agreed well*** *from one instrument to another* ***within the same instrument type (AIS or NAIS)****, especially for negatively charged particles.* ***However, once again, the NAISs display concentrations sometimes an order of magnitude higher than the AISs depending on the particle diameter.*** *This difference is also observed when looking at the raw electrometer signal on the right panels.* ***The problem is bigger at small currents or concentration.****"*
Similarly, for figure 6b, we added:
"The instruments agree well with each other, although a difference of about an order of magnitude can

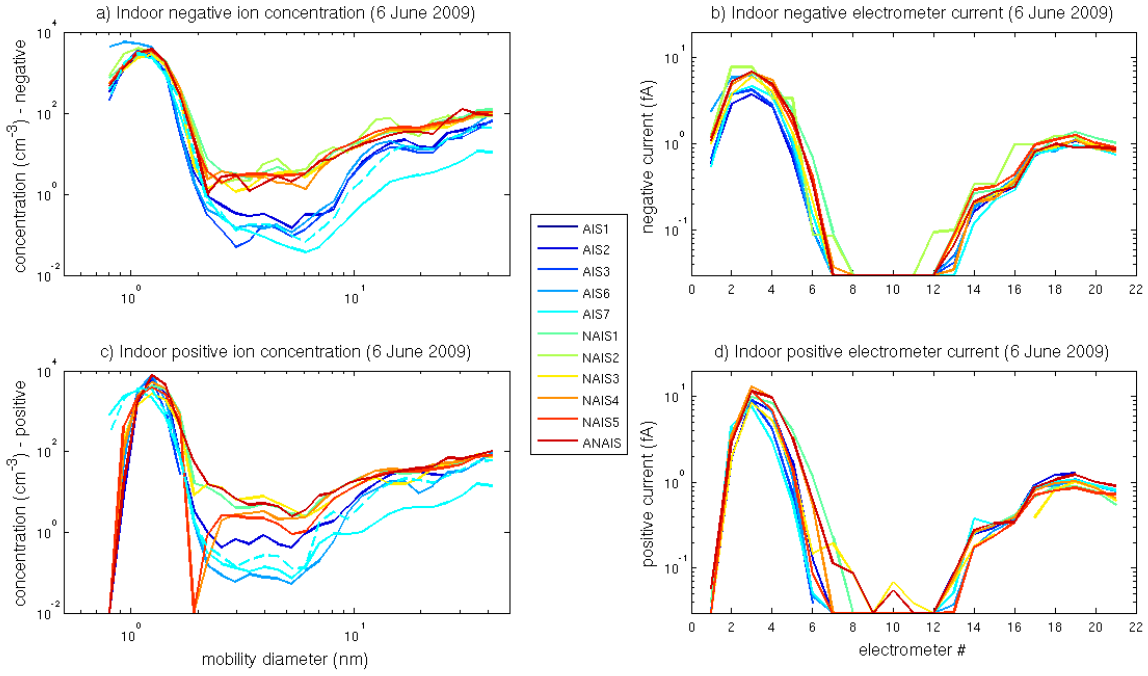
be seen between instrument types at certain diameters. At concentrations approaching the detection limit, the difference can be explained by the difference in background concentrations."

Along the same lines, the use of notched box plots in Figure 5 would allow the authors to show statistically significant agreements between the instruments, rather than the 25/75th percentiles, which hold no real significance.

The box plots are now notched to better reflect the statistical significance of the data points. However, the notches are so small that they are barely discernible. This is mostly due to the large number of data points used in the comparison. The text has not been modified in this case.

The errors and fundamental limitations in the instruments are not mentioned, but in Figure 4, the currents go down to 0.01fA which is approaching the limits of what can be measured. What is the resolution and sensitivity of the electrometers used in this and the other instruments, and how do they propagate through the inversions to affect the final results? Presumably these errors are smaller than the variability between different instruments, but it would be more rigorous to demonstrate this.

According to the manufacturers (personal communication), the sum of all noise components should be around 0.03 fA for an average of one minute. In practice, 0.03 fA corresponds to about 3 standard deviations in a one minute sample. To reflect this noise problem into the manuscript, a sentence was also added in section 4.2.1 and modified Figure 4 (now Fig. 6) using 0.03 as a minimum value. As we are evaluating a commercial instrument, we cannot assess the propagation of the current uncertainty in the inversion process.
"In both cases, if the median was a negative value, the value was replaced by $1X10^{-2}$ cm^{-3} for the concentrations and by 0.03 fA for the currents in order to facilitate visualization in logarithmic scale. The detection limit of the electrometers due to the noise is considered to be around 0.03 fA."
As for reference instruments, the CPC and aerosol electrometer's properties are described in section 3.2: "The 50% cut-off size of the CPC was 3 nm, while the electrometer, in principle, detects all ions and charged particles with a noise level of about ~300 cm-3.". The other instruments used in the intercomparison phase are described in their own reference papers and their limitations were taken into account in the analysis.



The paper is quite long as it stands and the use of more diagrams would break up the text and also perhaps reduce the words needed for explanation of the instruments. The introduction could also be shortened, for example, definitions of the aerosol indirect/ direct effects are not needed, and the full list of exotic locations of air ion measurements is also unnecessary.

We agree with the referee and the introduction was shortened to focus more on the instruments evaluated in this paper. The aerosol direct and indirect effects were removed from the introduction, as well as the list of field measurements, replaced by the overview by Hirsikko et al., 2011.

The discussion of other types of air ion spectrometer in the introduction is not especially well written and could usefully be improved. In particular, the first part of paragraph 2 on page 1 contain various repetitions and ambiguities. Do the techniques bringing particles to charge equilibrium charge them artificially, for example? The first full paragraph on page 4 implies that air ion spectrometers were only developed in response to the need for better measurement of new particle formation events. However, in the next paragraph, the long-established Estonian work is referred to. All the spectrometers used in this paper appear to be based on the highly-respected Estonian ion spectrometer heritage which goes back many years, and this should be explained before the discussion of new particle formation, which is a relatively recent motivation.

We are grateful for this piece of advice and have modified the introduction accordingly. We believe that the introduction is now shorter and that we got rid of repetitions and anachronisms. We hope that it is also better written.

Finally, the title should be shortened to "Intercomparison of air ion spectrometers" since the paper is only "a basis for data interpretation" for the relatively small group of people working with these specific instruments. The broader community will not be reading this paper to learn about data interpretation, but rather to learn about the results obtained, therefore the shorter title seems more relevant. The specific "data interpretation" motivation could instead be mentioned in the text.

We now think that we understand the referee's concern: our paper does not mean to be interesting

only for data analysts but rather for all people who have or will ever have to use numbers provided by an air ion spectrometer. To better reflect the spirit of our paper and avoid losing readership among non-data analysts, we have changed our title to "Intercomparison of air ion spectrometers: an evaluation of results in varying conditions".

Technical corrections:
Abstract: define all acronyms used
ANAIS, DMPS and BSMA are now defined.
Page 9 line 202: define a Hauke-type DMA
We added the reference Winklmayr et al. (1991) at the beginning of section 3.2 about the so-called Hauke setup.
Winklmayr, W., Reischl, G. P., Lindner, A. O., and Berner, A. (1991). A new electromobility spectrometer for the measurement of aerosol size distributions in the size range from 1 to 1000 nm. J. Aerosol Sci., 22:289–296.
Page 16 line 369: second column of what?
We corrected it […] In the second column of Fig. 2, […].
Page 18 line 418: units are missing
Corrected
Figure 4 units of concentration are missing
This was corrected for figures 3 and 4.
Table 2 define acronyms in caption
This was done.
References: update papers in ACPD to ACP (eg Hirsikko et al)
Yes, two references were updated.