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Atmospheric Measurement Techniques Discussions



# *Interactive comment on* "The mathematical principles and design of the NAIS – a spectrometer for the measurement of cluster ion and nanometer aerosol size distributions" *by* S. Mirme and A. Mirme

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We thank the referees for their helpful comments.

## 1 Referee #3

**Comment 1.1** *Question about Millikan equation (page 7412, equation 4):*

The Millikan equation in widely used for these sizes and specially with the Tammet correction has been shown to work well enough. We can easily replace the size-mobility relation when necessary.

**Comment 1.2** *Question about the negative values.*

Negative values will occur in any case when signal is close or below the noise level. Finding an inversion matrix and regularization parameters that would give the best possible resolution while avoiding deconvolution artifacts in is a difficult task. The resolution is higher in the cluster range and lower in larger sizes. There certainly is room for improvement and we are continuously working on it.

**Comment 1.3** *Question about calibration aerosol.*

We agree that improving the quality of calibration aerosol is most important.

## 2 Referee #4

**Comment 2.1** *It should be mentioned more clearly what is the size and time resolution of the NAIS?*

The maximum time resolution of NAIS has not been recently studied. In practice 1 s average data is usable. Increasing the time resolution further is probably possible but requires some enhancements in data processing algorithms.

The size resolution is dependent on the signal to noise ratio. Higer noise causes stronger regularization and thus decreased resolution.



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**Comment 2.2** *How are the transfer functions in comparison to other mobility spectrometers?*

The transfer functions are similar to other DMA-s. The shape is determined by relation between sheath and sample flowspeeds. Early NAIS transfer functions used to be asymmetrical due to turbulences in the inlet tract but this has been considerably improved in later instruments.

**Comment 2.3** *What are the main advantages and disadvantages of the NAIS?*

The instrument is quite robust, can operate without human interaction for long periods and has a good combination of size range and time resolution.

The electrical aerosol spectrometry method is unable to measure neutral particles in the same size range as charger ions (i.e. below 2 nm). The sample flowrate of NAIS is quite high. The time resolution in the larger end of the size range is limited by the spreading out of the airflow front in the analyzer.

**Comment 2.4** *How are multiply charged particles taken into account in the mathematical model? What kind of limitations does it cause to the NAIS spectra that the >40 nm size range is not measured?*

The mathematical model considers the whole charge distribution for each of the modeled particle sizes. The deconvolution does not see the whole mobility distribution for large particles near the edge of the measurement range. Consequently the resulting size distribution is incorrect – the concentrations near the edge are overestimated and deconvolution artifacts may appear.

**Comment 2.5** *Is the charging efficiency the same for the both polarities? Which polarity is plotted in Fig. 3? How would the plot look like for the other polarity?*



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The difference between positive and negative charging efficiency is insignificant compared to the uncertainty level of the measurements. In the present NAIS instrument model the same efficiency is used for both polarities. A sentence was added about that to the "Charging" secion.

**Comment 2.6** *The problematics of the particle mode spectra in the sub-2 nm size range is not really addressed at all. Asmi et al. (2009) and Manninen et al. (2011) reported that the lower detection limit of the NAIS is* $\sim$ *2 nm.*

A paragraph about the issue was added to the "Charging" section.

**Comment 2.7** *Abstract: Why did you change the name of an instrument which is widely already used and several publications are written? The Neutral cluster and Air Ion Spectrometer (NAIS) is already established name for the instrument. In my opinion, changing that name for this instrument is not correct.*

The term "neutral cluster" caused some confusion. So we decided to prefer the new name "Nanometer aerosol and Air Ion Spectrometer". Most of the measurement size range 2 – 40 nm is not clusters. The new name also hints to the similarity between NAIS and the "sister instrument" Electrical Aerosol Spectrometer (EAS).

**Comment 2.8** *Introduction: Page 7406, lines 15 onwards: Citations should be updated when summarizing the current status of sub-3 nm aerosol particle measurements. There are alternative methods nowadays to measure also the size distirbution at sub-3 nm size range e.g. a scanning Particle Size Magnifier (PSM, Vanhanen et al. 2011) and e.g. sudies reported by Jiang et al. (2011a,b) and Kulmala et al. (2012 and reference therein).*

The paragraph was slightly reworded and references were added.



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**Comment 2.9** *Page 7406, line 26: reference to Wiedensohler et al. (2012) paper should be added when the SMPS and DMPS measurements are mentioned. The authors should also notice the importance of this paper as motivation to their work. Wiedensohler et al. (2012) showed that the disagreement between standard mobility spectrometers below 20 nm is significant. Thus, alternative method to measure nucleation mode is needed, such as the NAIS.*

The reference was added.

**Comment 2.10** *Page 7407, lines 4-7: Perhaps you could consider citing a paper by Hirsikko et al. (2011) when talking about different ion measurement. They are well reviewed in that paper. Hirsikko et al. paper should be also mentioned in the last chapter of the results and discussion when talked about ambient measurements with the NAIS.*

The Hirsikko paper is already mentioned in the last chapter of the results and discussions.

**Comment 2.11** *Methods: Page 7408, line 19: "There are more than ten NAIS instruments in use today." Please update if needed?*

Updated to "more than 15".

**Comment 2.12** *Page 7415, line 19: Define what is ARMA?*

Reworded and added the full name "autoregressive-moving-average model". ARMA is a well known term.



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**Comment 2.13** *Calibration methods: Page 7419, line 26-28: Why are the particle losses of the inlet tract not a measurable parameter in the calibration?*

The geometry of the preconditioning unit is quite complicated. The losses depend on the exact airflow profile and turbulences. These may be different when the unit is separated from the instrument. And it is difficult to model it on a computer.

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Interactive comment on Atmos. Meas. Tech. Discuss., 4, 7405, 2011.