Atmospheric
Chemistry
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Discussions
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Interactive comment on "Trends in new particle formation in Eastern Lapland, Finland: effect of decreasing sulphur emissions from Kola Peninsula" *by* E.-M. Kyrö et al.

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The authors thank warmly the Anonymous Referee for his/her good and constructive comments that increased the value of this paper. It was especially good that the Referee pointed out some misleading parts from the manuscript that are now corrected. The authors have now concerned all of the comments and made the following corrections:

Comment 1: One of your aims is to compare the results from Eastern Lapland to those from Western Lapland. However, in order to understand what is similar

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and what is different in those locations, you should characterize first a bit more the local conditions in both places (also in relation to elsewhere in the Arctic / boreal region (and also to outside Finland if possible)). So please, add some more details for the basis of the comparison (e.g. latitude, altitude, ecosystem type, distance from major SO2 sources) when you first make this comparison (p. 30729)

We have now modified to the text and added a description of the differences between Pallas and Värriö.

Comment 2: p. 30732: 'Contrary to our findings, Hamed et al. (2010) . . . ' Why do you think this finding is contrary to your findings in Värriö? Please elaborate a bit more.

Värriö is located in the northern edge of the boreal zone, and despite of the sulphur pollution from Kola, is very clean background station. The study by Hamed et al. (2010) on the other hand, was done in polluted urban settings, which have much less emissions of natural organic compounds. Recently e.g. Ehn et al. (2014) showed that in a boreal environment, extremely low-volatile organic compounds (ELVOCs) contribute significantly to the nanoparticle growth. The importance of ELVOCs to the early steps of the growth is likely to be even higher in the north. This difference is the most probable reason for the differences in our study compared with Hamed et al. We added to the text following explanation and the reference to Ehn et al., Nature, 2014.:

"Both SO2 and organic compounds contribute to the value of J3 and the importance of extremely low-volatile organic compounds (ELVOCs) is likely to be much higher in the boreal region (Ehn et al., 2014) than elsewhere and even higher in the pristine areas in the northern edge of the boreal zone."

Comment 3: p. 30737 'We calculated the percentage of time that the air masses had arrived to Värriö over Kola for each month. . .' please move the explanation how the trajectory calculations were done to Methods-section.

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Corrected.

Comment 4: What do you mean by filtering (p. 30737 last line and the discussion that follows)? Please first introduce the emission policy in a more general way and then go into details in how it was implemented.

We have now modified the text and deleted the unnecessary information of the filtered data. The text was somewhat misleading before, and we gave more information than what was needed. The main idea is that even though the overall emissions have decreased, the amount of deactivated emissions has stayed the same. Now the paragraph is as follows:

"The main source of anthropogenic atmospheric SO2 in Värriö is the industrial activity in the Murmansk Oblast region. Since the 1990s, the Murmansk region has slided into a socio-economic decline, which in turn has had an impact on the overall emissions of the region. From 1992 to 2011 the overall amount of atmospheric emissions has decreased from 617 thousand to 263.1 thousand tonnes per year (Federal State Statistic Service of Russia, 2013a). In particular, the overall amount of emitted SO2 from stationary sources has decreased from 275.8 to 194.6 kT/yr for the period from 2000 to 2012. For the period 2001-2012 the amount of SO2 emitted primarily from combustion for energy production (heat and electricity) has also declined from 96.3 to 65.8 kT/yr. The amount of caught and deactivated SO2 emissions from stationary sources has remained the same, being 134.7 and 135.2 kT/yr in 2001 and 2012, respectively (Federal State Statistic Service of Russia, 2013b)."

Comment 5: The Conclusion needs rewriting: p30739: 'higher concentrations of SO2 and H2SO4...' please clarify the comparison (higher than what?)

Our meaning was to say that high concentrations of SO2 and H2SO4 advance the onset of nucleation, not to compare it with any values so we have changed the word "higher" to "high" in order to avoid misleading interpretations.

Comment 6: I would prefer you discussing the actual measure instead of a loose 'data' (lines 22-24). For example, 'These data are entirely associated with the Kola sector' – I presume you mean the high SO2 concentrations? In the next sentence, 'clean data' – I presume you mean days with low SO2 concentrations?

Here we don't discuss only about one parameter or measure, but the whole dataset that is characterized with either low or high SO2 concentrations. Also, we haven't divided the data into days with high or low SO2 but this division is based on the 1-h averaged data. We have now modified the text from those places it was possible to use other words than vague "data":

"Firstly, when considering only those times when the concentration of SO2 exceeded the 95th percentile, the yearly sum of SO2 correlated very well with the yearly sum of nucleation mode particle concentration. These data are entirely associated with the Kola sector. For the times when SO2 was lower than the overall median value, the correlation was much lower."

Comment 7: p 30739 line 28 and p 30740 line 2: 'The relative difference' – please specify which measure you speak about?

We apologize for the misleading use of word "between". What we meant was: "The relative difference in air masses coming over Kola on nucleation days compared with all days was several tens of percentages through late winter to autumn ..." The text has now been changed accordingly.

Comment 8: p 30740: 'Until now, there has been no clear evidence on the cleaning of emissions in the Murmansk Oblast region.' What do you mean by this? evidence regarding what? To me the official published statistics are clear and form an evidence on cleaning of emissions. Please clarify!

Referring to the modified text in 3.2.3 (Comment 4), our main finding is that the reduced emissions are due to socio-economic activities in the area, not because of more effi-

cient cleaning techniques since otherwise we would see a change in the deactivated emissions. We have now modified the last paragraph in the conclusions followingly:

"In the future, the trends in the NPF in Eastern Lapland will likely depend on the overall human activity in the Murmansk Oblast region, the general cleaning of the emissions by new filtering techniques and deactivation methods in there, and changes in natural biogenic emission. Our analysis of the official statistics has shown that the reduction of emissions from stationary sources in the Murmansk Oblast region is more likely to be due to reduction of socio-economic activities in general, rather than due to particular changes in cleaning techniques utilized by industrial establishments. It is very likely that everywhere close to large sources of anthropogenic sulphur emissions with simultaneously low background aerosol concentrations, such as close to Arctic shipping routes, the trends in NPF are governed by these factors. Therefore, due to opening of new shipping routes and increased marine activity, it would be important to conduct more long-term measurements of NPF in the Arctic.

Comment 9: Table 1: give the time range for the mean

Corrected.

Comment 10: Table 2: temperature – please specify which temperature value this is (annual mean/min/max, summer/winter/spring/fall…)?

The Table 2 represents trends calculated from 1-h averaged data using two different methods: least squares covariance method which takes into account the seasonality and Mann-Kendall method which doesn't take this into account but gives confidence intervals for the trends.

Comment 11: General remark on figs: In all figures that have more than one panel, the panels should be named (A, B, C…) There are quite many figures. Consider if some of them could be left out?

fig. 3: add: The black curves in A) denote the …

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Corrected.

fig. 4: give time range also here (average of years…)

Corrected.

fig. 5 (B): the legend panel is covering some black bars. Please give this information in the figure legend (remove the legend panel from fig 5B) or position so that the information is visible. The %-change can be given in figure legend.

The figure has been now re-formatted so that all the bars are visible.

Fig. 8: orange line is poorly visible. Can you change the colour to make it more visible?

Fig. 10: please give A and B also in legend. In A the orange line is also very poorly distinguishable.

The orange lines from figs. 8-10 have been re-coloured. Also other corrections that were pointed out, have been made.

fig 12 legend has the A and B but figure panels are missing here

Corrected.

fig. 12: How can the explained % be >100? please explain in figure legend this confusing issue.

In cases where sulphuric acid explains more than 100

Is the fig 13 needed – it is rather simple and Table 2 already has the same information (or does it?)

The figure 13 shows different information than Table 2. However, we agree with the referee that it is not needed and we have removed it from the manuscript. Figure 13 showed the trend in yearly mean spring temperatures whereas the temperature trend in Table 2 is calculated from the running mean of 1-h averaged measurements with two

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methods, one that takes the seasonality into account and one that doesn't but provides us information of the uncertainties of the slopes.

Fig. 15: 'faction' revise to 'fraction'. What does Fig 15B mean? relative difference to what? Please clarify.

Corrected. Fig. 15B and the meaning of relative difference are explained in detail in the text in the end of section 3.2.2.