

Interactive comment on “Long-term trends of black carbon and sulphate aerosol in the Arctic: changes in atmospheric transport and source region emissions” by D. Hirdman et al.

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Dear Anonymous Referee #1, Thank you for your positive comments on our paper.

We have taken all your comments into consideration and hope that you will find our responses and changes to the manuscript satisfying. Regarding your questions:

Page 12136, lines 16 / 22: “Description of available data at measurement sites. It would be helpful to state locations (lon/lat) of the sites here, where they are first mentioned, rather than in Sec 2.1.1. Alternatively, lon/lat coordinates could be added to Table 1 and referred to here.”

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The locations of the stations are now stated in Table 1. As suggested, we do now refer to this table when the stations are first mentioned in the introduction.

P12141, L19-21: “It is not obvious to the reader why the clean-sector screening may affect the representativeness of the data for analysing the potential source regions. Please add in a sentence to further explain.”

We have added the following explanations to the paper: “This screening effectively excludes direct transport from most North American source regions. Thus, the statistical analysis of North American source regions of BC for Barrow relies on indirect transport events, which are likely associated with larger errors in the simulated transport. In addition, signals of BC from source regions both in North America and on other continents are likely often mixed during such indirect transport events, which make a clear identification of source regions in North America more difficult.”

P12143, L27-28: “An alternative explanation to changes in sources may be changes in processing affecting efficiency of loss processes en-route. A caveat acknowledging this possibility should be added with a statement that the analysis will assume this is not significant.”

This is indeed a very important point to consider and we have now added a short discussion about this: “However, trends in precipitation or other scavenging processes along the major transport pathways the stations may also influence the trends of the measured species concentrations for particular clusters. Such trends (New et al., 2001; Adam and Lettenmaier, 2008) are not homogeneous across the Arctic and their overall impact on aerosol wet scavenging has not been studied. Furthermore, the trends of acidifying species in Arctic precipitation agree well with reported emission trends (Hole et al., 2009), whereas changes in removal efficiency seem to have a smaller

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influence on the reported deposition values. In this study we therefore assume that the influence of temporal trends in scavenging processes is not significant allowing us to separate the effects of changes in atmospheric transport to the Arctic from effects of emission changes in a few important source regions, on the Arctic EBC and sulphate concentrations.”

P12144, L6: “It is not obvious what is meant by ‘number of cases’. Is this the number of points from which the backward transport model is started for each observation time series? Please clarify.”

The number of cases resembles the number of model calculations linked with the related measurements. We hope that is made clearer by the addition of the following text: “Here, i and j are the indices of the latitude/longitude grid and n runs over the total number of cases N , where each case resembles a model calculation linked with a corresponding measurement and where both are averaged over the same time interval.”

P12145, L5: “It is not obvious what the ‘silhouette technique’ is used for or is intended to account for. Please add a sentence just to clarify this.”

We have added the following statement: “We choose to apply the silhouette technique in order to further establish our conclusions from the visual analysis. We found it fitting since this technique measures how closely the data within each of the clusters match each other and how loosely they match the data of the other clusters.”

P12150, L26/27: “‘‘reasonably well positively respectively negatively correlated..’’ This doesn’t make sense - please correct / re-write more clearly. In addition, ‘reasonably well’ is subjective. Please quantify correlation / state significance.”

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This was indeed unclear. We have rewritten the sentence to read: “The strongest correlations between the seasonal NAO index and the frequency of each cluster are found for Alert and Barrow, where the frequency of the NE clusters are correlated with the NAO index, whereas the frequency of the NA clusters are anticorrelated with the NAO index (Table 2).”

P12152, L7-10: “‘‘The annual EBC concentrations decrease at a rate of -9% / yr...’’ This sentence does not make clear whether the -9%/yr trend is over the same 2001-2007 period as the Eleftheriadis et al., (2009) trend that is being compared, or over a different period. Please re-write this sentence to make this clear.”

Thank you making us aware of this section in the text. It has now been rewritten as follows: “The annual EBC concentrations decrease at a rate of $-9\% \text{ yr}^{-1}$ ($-1.44 \pm 0.8 \text{ ngm}^{-3} \text{ yr}^{-1}$) (Fig. 13c). The decrease is consistent and significant for all clusters but ENE, which shows a statistically significant increase in winter ($+9.4\% \text{ yr}^{-1}$ or $4.1 \pm 3.3 \text{ ngm}^{-3} \text{ yr}^{-1}$) and this increase might be related to emission increases in China. Comparing these results to previous trend studies, we find that the annual mean EBC concentration measured at Alert (1989-2008) show an even larger decreasing trend than previously presented (-72% against -54% during 1989-2006 (Sharma et al., 2006)). Also the EBC at Zeppelin (2002-2009) showed a stronger negative trend ($-1.44 \pm 0.8 \text{ ngm}^{-3} \text{ yr}^{-1}$), than the decrease of $-0.95 \text{ ngm}^{-3} \text{ yr}^{-1}$ reported by Eleftheriadis et al. (2009) for the time period 2001-2007.”

P12154, L1: “‘‘agrees quite well..’’ is subjective. Please quantify agreement.”

We agree that this statement may be rather subjective; however, the remaining part of that section already quantitatively compares the agreement between several studies including the one referred to here.

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