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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A trajectory analysis of atmospheric transport of black carbon aerosols to Canadian High Arctic in winter and spring (1990–2005)" *by* L. Huang et al.

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Reply to Referee #1

The authors thank this referee for the helpful comments, questions, and suggestions, which have led to improvements in the quality of the revised manuscript. Referee comments and questions are labeled with numbers, and author comments and answers to the questions follow.

1) My only more general comment deals with the emission inventories and the corresponding emission intensities. To my understanding these inventories do not consider biomass burning (BB) yielded aerosol. Nowadays, BB is considered as a major source

affecting BC concentrations in the arctic (see e.g. Warneke et al. 2010), especially during spring-time. I would like the authors consider this in their paper, or at least mention it somehow.

It is true that the emission inventories used in this study do not consider biomass burning emissions. But the neglect of BB emissions would not significantly affect the results presented in the manuscript. It would not affect the results for winter because the BB emissions occur mainly in spring and summer. Although springtime BB emissions are considered as important sources affecting the Arctic BC, the impacts are mainly on BC concentrations in the free troposphere (Warneke et al., 2010). For instance, Warneke et al. (2010) showed that "Only in the boundary layer most particles consistently had no BB components (Figure 2c)." Since the current study focuses on the inter-annual variability of BC concentrations observed near the surface, the neglect of BB emissions would not significantly affect our results. We have added discussion in the first paragraph of Section 2.3.

2) Is it possible that not only removal processes, but also sources can get "hidden" in the b- factor ("cluster specific proportional constant")?

Assuming that the contributions from different sources to the surface BC concentrations measured at Alert are superposable, the contributions from geographic locations other than those already considered in this study (i.e. North America, Europe, and Former USSR) are accounted by regression residuals. For both January and April dataset, the 16-year average regression residuals are less than 15% of the average BC surface concentrations, which suggests that the overall contribution from other locations than those considered in this study is relatively small.

Besides removal processes, however, it is possible that sources that are not included in the emission inventories used in this study (such as biofuel combustion) may affect the b factors. Based on the emission inventory of Bond et al. (2004), the global over emissions of BC from fossil fuel is about two times higher than those from biofuel

consumptions. Based on the same emission inventory for 1996, the overall emission of BC from fossil fuel combustion is about 9 (4) times higher than that from biofuel for the region north of 50 °N (30 °N). And the major biofuel emission is from the South and East Asia. Therefore, b factors would not be significantly affected by neglecting BC emissions from biofuel combustion.

3) There appears to be some ambiguity in the parameter E appearing in equation (2) and the text. Somewhere it is referred to as “surface flux”, somewhere else as “emission intensity”. These quantities also appear in figures 1 and 4, but having different dimensions. Are they one and the same thing, or different quantities? Please clarify.

They are one and the same thing in the first version of the manuscript. To be consistent, it is referred to as "surface flux" in the revised manuscript.

The unit of surface flux (previously "emission intensity") in Figure 4 was wrong. It should be the same unit as the one used in Figure 1. It has been corrected in the revised manuscript.

4) Table 3: how would one interpret the b factors? What does a high or a low value mean? Maybe some comments on the p-values might be useful too; it seems that for some clusters estimating the b is easier than for others. What does this tell about?

In principle, atmospheric processes that modify BC concentration during the transport of BC from source regions to the receptor contribute to the b values. The b factors in this study are source region and pathway specific, and they have a unit of s/m. Presumably, the b factors would mainly depend on mixing heights (m) in the source regions and aerosol removal processes (1/s). For example, greater mixing height in a source region would result in more dilution of the initial BC concentration in the air, and thus reduces the b value associated with that specific source region. At the same time, if an atmospheric transport pathway is associated with relatively fast aerosol removal processes (possibly due to long distance of transport, fast transformation from hydrophobic to hydrophilic particles, frequent precipitation events, and so on), one would expect

a small b value specifically for this pathway. We have added this discussion to the end of Section 2.4.

The p-values shown in Table 3 are provided to justify the significance of the estimated b values from linear regression analysis using the least squares method. Table 3 suggests that the estimated b values are significant at a confidence level of 90%.

5) Figure 1: BC surface fluxes for the European Union, former USSR and North America are shown. Please be more specific how the areas are defined. Are they restricted only to the areas relevant here? If they cover the whole land area, what proportion of the emission flux is important if transport to Alert is considered?

Areas for European Union, former USSR and North America are based on political boundary definition of the Gridded Population of the World, version 3 (GPWv3). The areas used in this study cover the whole land area of these regions. The surface fluxes were obtained by dividing the annual BC emission from one region by its surface area and by time (i.e. one year). We have added this information in the second paragraph of Section 2.3 in the revised manuscript.

Unfortunately, the current study cannot determine what proportion of the emission flux is important to the surface BC concentration observed at Alert. It is due to the consideration of potential source regions in this study only involves the broad regions of Europe, former USSR, and North America. A uniform BC emission flux was assumed for each of these regions without considering the geographic distributions within the broad land. To determine the relative importance of sources within these regions requires the use of a gridded emission dataset. The choosing of the horizontal resolution of BC emissions, then, needs to be made with consideration of the uncertainties in trajectory calculation.

6) Figure 4 and relevant text in the manuscript: prior to this figure, the subject has considered Europe and the former USSR separately. Is there a reason to suddenly change the focus to Eurasia? This is a matter of opinion of course, but I would still like to see

the contribution from the Europe and the former USSR separately. I find it interesting that even though figures 2a and 2b indicate quite few trajectories arriving from the Europe, this seems to be the main source area contributing to the BC concentrations.

The reason for combining contributions from Europe and former USSR in Figure 4 was to compare our estimations with those from recent studies by Shindell et al. (2008) and Gong et al. (2010).

On a 16-year average base, the former USSR contribution to Alert BC is about 60±15% (average±standard deviation), and the relative contributions from North America and Europe are 19±9% and 19±13%, respectively.

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