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## ***Interactive comment on “Atmospheric black carbon and sulfate concentrations in Northeast Greenland” by A. Massling et al.***

**A. Massling et al.**

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Response to reviewer 1:

Minor comments:

**Abstract:** I strongly suggest including more quantitative results in the abstract. It is currently written in very general terms. For example, what are the seasonal mean and standard deviations of the aerosol concentrations? What is the correlation between BC and sulfate? How well did EC and BC measurements "compare"? How "good" was the agreement between modeled and measured concentrations of BC and sulfate?

**Author:** This is right. In the revised version of the manuscript, the most important

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numbers will be listed in the abstract as they are also listed in the summary part.

Section 4.4: It is quite interesting that measured BC and sulfate concentrations are more highly correlated than measured BC and EC concentrations!

Author: This is also what made us surprised. We think that these findings are mostly based on the different instrumental techniques (used here for EC and BC measurements) which are also discussed in detail in the literature and partly based on possible local pollution for the EC measurements, which cannot be fully excluded as these measurements were taken in the camp as described in the paper.

11467,4: The reference to Flanner et al (2011) is not appropriate here, as this particular paper did not explore BC impacts. Flanner et al (2007, doi:10.1029/2006JD008003) would be more appropriate.

Author: Thank you for that suggestion. This reference will be changed in the revised version of the manuscript.

11467,10: "unless they do not appear in very large sizes" -> This would be more clear if it were worded as "unless they appear in small sizes". Would this change retain the meaning?

Author: What we mean here is as it is said. If they appear in larger sizes their CCN ability maybe potentially high. From traffic BC is emitted between 50 and 100 nm meaning the CCN ability of these particles is not very high.

11467,22: "IPCC, 2013" -> The accepted practice is to cite specific chapters of the report.

Author: Yes, you are right. We may leave this to the Crutzen reference which is really the best one.

11468,16: "However, Huang et al (2010) demonstrated that a reasonable agreement can be obtained..." - Were there any specific model adjustments made by Huang et al

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to achieve this agreement? Otherwise, I suggest at least listing the model applied in that study.

Author: The purpose of the paragraph was to emphasize that there are large discrepancies between models and measurements in the Arctic, especially for models which not have been focused on the Arctic. The results of Huang et al (2010) show that with this focus on Arctic it is possible to improve the performance in the Arctic. Our model, the DEHM model, has been applied for study transport of air pollution to the Arctic since 1993 (see Christensen, 1997). Therefore one of the main issues with the model development has always been the performance of the model of e.g. sulphate in the Arctic.

11468: Somewhere in this section I suggest clarifying that the measurements reported in this study were made near the surface, and that radiative forcing depends on the entire column burden.

Author: Yes, this is reasonable and will be mentioned in the revised version of the manuscript.

11470,11: "Multi Angle Absorption Photometer" has already been referred to as "MAAP" earlier in the sentence, so it doesn't need to be spelled out again.

Author: Yes, we will use the abbreviation in the further text of the revised version of the manuscript.

11470,13-20: Logically, this paragraph could perhaps be moved up or merged with the earlier discussion on ranges of measured absorption coefficients for BC, before describing the absorption coefficient value that was settled on (lines 8-12).

Author: Yes. We will combine this with a previous paragraph. This fits much better in this context and any repetition is then avoided.

11471,15: Please briefly describe the sources of this local pollution.

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Author: The is mainly ground transport in the camp, some burning of garbish for some small time periods and the starting and landing of aircrafts on irregular schedule (only few take-offs during most of the time). This will be mentioned in the revised version of the manuscript.

11473,24: Please describe these "simple time profiles". How, precisely, are the annual emissions distributed in the model?

Author: We add some text which describes where the time profiles are obtained from. Original text: These yearly emissions are distributed to daily or hourly emissions using simple time profiles resulting in emissions on shorter timescales having larger uncertainties compared to the total yearly emissions. New text: These yearly emissions are distributed to daily or hourly emissions using simple time profiles resulting in emissions on shorter timescales having larger uncertainties compared to the total yearly emissions. These time profiles are available as data files from the EMEP model website, ([www.emep.int.](http://www.emep.int.), see also Simpson et al, 2012). The seasonal time profiles are only applied for the European countries.

(Reference: Simpson, D., Benedictow, A., Berge, H., Bergström, R., Emberson, L. D., Fagerli, H., Flechard, C. R., Hayman, G. D., Gauss, M., Jonson, J. E., Jenkin, M. E., Nyíri, A., Richter, C., Semeena, V. S., Tsyro, S., Tuovinen, J.-P., Valdebenito, Á., and Wind, P.: The EMEP MSC-W chemical transport model – technical description, *Atmos. Chem. Phys.*, 12, 7825-7865, doi:10.5194/acp-12-7825-2012, 2012.)

11474,6: "Particle diameter of 1 $\mu$ m". Earlier (11473,10), 1 $\mu$ m is listed as the upper particle size limit. Please describe more precisely the BC and sulfate particle size distributions that are assumed in the model.

Author: The text at (11473,10) will be modified to describe more precisely the bulk representation of the BC and sulfate particles. Old text: Both BC species are assumed to have an upper particle size limit of 1  $\mu$ m in diameter. New text: Both BC species and sulphate are assumed to be a bulk representation of the particles by a mean particle

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diameter of 1  $\mu\text{m}$ .

Section 4.1, first paragraph: I suggest listing the annual mean values in this paragraph, to accompany the maximum and minimum values that are already listed. (Later, seasonal mean values are described.)

Author: We do not think that this is reasonable as we only have one annual mean value and two half-annual mean values because of the total time period of data available. This is one reason why we have been reporting the seasonal values based on the whole time period measured.

11477,12-18: Are there any other indications or evidence of biomass burning that could be introduced to support this discussion?

Author: From receptor analysis using PMF and COPREM we failed to identify the contribution from biomass burning (Nguyen et al. 2013, ACP). From other high Arctic stations we expect that biomass contribution is significant and we have ongoing work to distinguish more efficiently between the various sources. We have thus measured the chemical composition of particles with a Soot Particle Time-of-Flight Aerosol Mass Spectrometer (SP-ToF-AMS) this spring at Villum Research Station.

11478,3: "about 1.5 to 2.5 higher" - Do you mean: "a factor of 1.5 to 2.5 higher"? If not, please include units.

Author: Yes, we mean that as a factor. This will be more clear in the revised version of the manuscript.

Section 4.3: Emissions are described as being the likely source of model-measurement differences, but the model physical representations could also be responsible for some or most of these differences, and I think this should be acknowledged more clearly here. This seems especially true because the model represents BC and sulfate as external mixtures, whereas the observations seem to indicate an internal mixture.

Author: Text will be added that model inadequacy in the description of physics, e.g the

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bulk external mixed representation of the particles also could be a reason for discrepancies between model and measurements. Old text: Discrepancies seen for BC (Fig. 3a) can be explained by the larger uncertainties of emission inventories used as input for the model of BC compared to emission inventories of sulfur dioxide and sulfate with relation to both the total amount and the temporal and geographical variations. New text: Discrepancies seen for BC (Fig. 3a) can be explained by the larger uncertainties of emission inventories used as input for the model of BC compared to emission inventories of sulfur dioxide and sulfate with relation to both the total amount and the temporal and geographical variations. Another important reason for these discrepancies could be due to model inadequacy in the model description of the physics, e.g the bulk external mixed representation of the particles.

11478,21: "changes in the emissions" - Do you mean interannual changes in emissions? Please clarify

Author: The text will be clarified. Old text: The reason for that might be changes in the emissions. . . New text: The reason for that might be changes in the interannual emissions. . .

Related, were year 2011-2013 emissions from GFED applied in this study? Please specify this on p.11473.

Author: On page 11473 it has been specified which years the GFED cover. Old text p11473: Furthermore, the biomass burning emissions are based on the Global Fire Emissions Database version 3 (GFED 3) (van der Werf et al., 2010), which have a horizontal resolution of a 0.5x0.5 on a monthly time step. New text: Furthermore, the biomass burning emissions for the years 1997-2010 are based on the Global Fire Emissions Database version 3 (GFED 3) (van der Werf et al., 2010), which have a horizontal resolution of a 0.5x0.5 on a monthly time step. For the model runs after 2010 the GFED 3 emissions for 2010 were used.

11480,3: What is meant by "modern fuels"?

Author: We mean emissions from wood combustion. This will be specifically stated in the revised version of the manuscript.

11481: "Sibiria" -> Siberia

Author: Thanks. This will be changed in the revised version of the manuscript.

11481,20: "and and"

Author: Thanks. This will be changed in the revised version of the manuscript.

11481,23: "substantially higher": By what factor? As with the abstract, please quantify the key results in Conclusions.

Author: We will like to give a quantitative value on this statement in the revised version of the manuscript as we have calculated that in Table 1.

11482,15: "...The most likely reason for this discrepancy is seen in the uncertainty of emission inventories for black carbon..." - The modeled sulfate concentrations are also substantially higher than measurements, however, so it seems the error in modeled SO<sub>4</sub>/BC ratio is also associated with sulfate biases. This should be acknowledged. More generally, I wonder if some of this bias could be associated with the model treatment of BC and sulfate as external mixtures (?).

Author: It is correct that the error in the modelled SO<sub>4</sub>/BC ratio is due to the overestimation of SO<sub>4</sub>. This will be changed in the text of the revised version of the manuscript. Old text: The most likely reason for this discrepancy is seen in the uncertainty of emission inventories for black carbon that are used as input variable for the model. Little information is known about these emissions with respect to their temporal and geographical variations. New text: The most likely reason for this discrepancy is the overestimation of modeled SO<sub>4</sub> concentrations, which probably is due to changes in the interannual emissions of SO<sub>2</sub>, that not have been included in the used emissions inventories. Model results from earlier years do not show this large overestimation.

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Figure 2: It would be helpful to add a subfigure showing a scatterplot and correlation statistics, similar to Figure 1.

Author: This is what is shown in Figure 4a.

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