

## ***Interactive comment on “The influence of cruise ship emissions on air pollution in Svalbard – a harbinger of a more polluted Arctic?” by S. Eckhardt et al.***

**S. Eckhardt et al.**

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We thank Daniel Lack for the constructive comments on our manuscript. In the following list we will answer the questions (which we repeat in italic) and explain how we implemented them in the manuscript.

*The International Maritime Organization is currently discussing the issue of the impact of shipping BC on the Arctic. The review of Lack and Corbett discusses some of this and I think it is worthy to note in the introduction and discussion that your work contributes a very unique data set to this discussion. It is important for policy makers to*

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*know what the contribution of shipping is to the Arctic area. For example, it is believed that about 2% of global BC is from shipping. In your study region you show that ships increase the summer BC burden by 11%. Although not directly comparable your data does provide room to discuss these issues without reaching beyond the scope of the work.*

This is an interesting point. However, our study is of a very local nature and it might be misleading to extrapolate our findings to the entire Arctic or compare them directly with global numbers. However, to put our findings in context we added the sentence: "This fraction can be compared with the global fraction of BC, 2%, which is due to shipping emissions (Lack et al., 2008)".

Lack, D., Lerner, B., Granier, C., Baynard, T., Lovejoy, E., Massoli, P., Ravishankara, A. R., and Williams, E.: Light absorbing carbon emissions from commercial shipping, *Geophysical Research Letters*, 35, 10.1029/2008gl033906, 2008.

*Introduction: Although the Arctic population is low, shipping emissions will also contribute to health concerns. Perhaps worth a mention (Corbett et al health study on ships) given that the Arctic Council has identified environmental and social effects of Arctic development as concerns.*

Yes, you are right, we mention this now in our manuscript: It has been found, that shipping-related PM emission have a significant influence on cardiopulmonary and lung cancer deaths (Corbett et al., 2007). Although the Arctic population is low, shipping emissions will also contribute to health concerns.

Corbett, J. J., Winebrake, J. J., Green, E. H., Kasibhatla, P., Eyring, V., and Lauer, A.: Mortality from ship emissions: A global assessment, *Environmental Science Technology*, 41, 8512–8518, 10.1021/es071686z, 2007.

*P3073 L23: I would recommend removing the Granier reference and associated text, while adding in the quantitative details of ozone from Dalsoren. I believe it is apparent*

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*that the scenarios of Granier are high and including the extreme scenario is a little distracting.*

We removed the Granier reference and added: It has been estimated that ship emission of ozone precursors could lead to a 10% increase in ozone in the Arctic lower troposphere.

We also updated the Dalsoren reference from ACPD to ACP:

Environmental impacts of shipping in 2030 with a particular focus on the Arctic region  
S. B. Dalsøren, B. H. Samset, G. Myhre, J. J. Corbett, R. Minjares, D. Lack, and J. S. Fuglestad  
Atmos. Chem. Phys., 13, 1941-1955, 2013

*General Comment: Biomass burning BC is a major source for the Arctic. Is it possible to estimate the contribution of biomass burning emissions to local BC during the period of this study? The timing of various sources is important, as you mention. It would be great to understand how much these sources contribute during Spring, summer, fall etc.*

Here we want to refer to a recent paper of ours (Stohl et al., 2013), where we determined the monthly BC contribution by source category (Figure 8 in Stohl et al., 2013). According to our model study, for Zeppelin biomass burning during the years 2008-2010 was most important in July and August, when more than 50 percent of the BC comes from this source. After September and before April this source is negligible.

*P3077 L3: You include 4 hours post-departure of the ship. Why not 4 hours prior?*

Adding these 4 hours was done mainly to allow the emissions to propagate to the station. A major emission pulse is expected when the ship leaves the harbor and it would not be immediately measured at the station.

*Section 2.4: How are the scattering corrections of the PSAP done? This requires a measure of scattering.*

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The PSAP's cross-sensitivity to particle scattering is corrected using the scheme of Bond et al. 1999. The scattering coefficient is provided by a collocated TSI 3563 integrating nephelometer.

Bond, T. C., Anderson, T. L., and Campbell, D.: Calibration and Intercomparison of Filter-Based Measurements of Visible Light Absorption by Aerosols, Aerosol Sci. Technol., 30, 582-600, 1999.

*Section 2.4: Can you justify a mass absorption efficiency of  $10 \text{ m}^2 \text{ g}^{-1}$  for fresh ship emissions?*

We are aware that Bond and Bergstrom (2005) recommend a mass absorption cross-section (MAC) of  $7.5 \text{ m}^2 \text{ g}^{-1}$ , but we interpret their results slightly differently. Even though the median value for the MAC values selected there for fresh combustion aerosol may be closer to  $7.5 \text{ m}^2 \text{ g}^{-1}$ , also the data of Bond and Bergstrom (2005) indicate an uncertainty range for the MAC between  $5 - 15 \text{ m}^2 \text{ g}^{-1}$  independent of the aerosol age (see their Figure 8). With such a large uncertainty range, it can certainly be debated whether the data median or the average of the uncertainty range should be used as best estimate, even though, considering the uncertainty, the discussion would be futile. We chose to use the average of the uncertainty range of  $10 \text{ m}^2 \text{ g}^{-1}$ .

Bond, T.C., and Bergstrom, R.W.: Light Absorption by Carbonaceous Particles: An Investigative Review. Aerosol Science and Technology, 39, 1-41, 2005

*How long does it take, for the enhancements observed due to ships, to return to a background? Can you estimate this for the case study?*

This is quite difficult as we don't know exactly when the emissions occurred. A major pulse is expected when a ship leaves the harbor but emissions are also expected upon arrival, when the ships are in the harbor and when they cruise in the fjord. From the one case study it seems it takes maybe 3 hours, and elevated BC concentrations lasting for about a couple of hours are also visible in other cases.

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*P3082 L10: What are the contributions and source regions to Arctic haze? I think this is worth mentioning, and also discussing that most current Arctic pollution requires long range transportation to get to the region.*

This relates also to the study mentioned above. In principle domestic burning and industry emissions from Europe, Asia and North America which are transported to the Arctic. In summer biomass burning. We have added the following sentence: In the Arctic, local pollution sources are very limited and most of the pollution observed near the surface is due to long-range transport from mid-latitude emission sources (traffic, industry, biomass burning, etc.), primarily located in high-latitude Eurasia (Stohl, 2006).

*P3083 L7: The comment on "entire year" refers to the yearly average of these pollutants correct? Be explicit here to be clear that the yearly average burden is currently low, however there are some days where the contribution from ships is significant.*

Yes you are right, we added your suggested sentence and replaced entire year by yearly burden: The yearly average burden is currently low, however there are some days for which the contribution from ships is significant.

*It is always concerning to me when measurement uncertainties are not presented and the impact of those uncertainties on results discussed. Most of this work is comparative in nature so this concern is reduced somewhat, however i believe it is still worth discussion*

Yes we agree, and it is not only the measurements uncertainty but for EBC also the conversion from the AAC to the EBC which has uncertainty. As the reviewer says, we mainly study relative enhancements, which means that systematic errors would largely cancel out. Concerning the AAC there are two types of uncertainties which have to be considered. One is related to the sampling statistics and one to the scattering correction, both are described in Bond et al., 1999. We added a description on this in the manuscript.

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#### References:

Stohl, A.: Characteristics of atmospheric transport into the Arctic troposphere. J. Geophys. Res. 111, D11306, doi:10.1029/2005JD006888, 2006.

Stohl, A., Z. Klimont, S. Eckhardt, K. Kupiainen, and C. Lunder: Why models struggle to capture Arctic Haze: the important role of the emissions. Atmos. Chem. Phys. Discuss. 13, 9567-9613, 2013.

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Interactive comment on Atmos. Chem. Phys. Discuss., 13, 3071, 2013.

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