

## ***Interactive comment on “Aerosol exposure versus aerosol cooling of climate: what is the total health outcome?” by J. Löndahl et al.***

### **Anonymous Referee #1**

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### **General comments:**

This paper calculates annual mortality that arises through aerosol exposure and aerosol cooling of climate from ship emissions. While it might be true that this is the first attempt to calculate the combined effect of aerosol exposure versus cooling from anthropogenic particle emissions on human health, it is certainly true that the approach the authors take is too simplified. The authors are (1) not using a sound method to calculate human health impacts, (2) do not present sufficiently new material to justify publication, (3) ignore quite a few studies that have been published on this topic recently and (4) do not perform a sophisticated uncertainty analysis. For these reasons which are further detailed below, I cannot recommend publication in ACP and rather strongly suggest rejecting this paper. This topic requires a careful scientific

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analysis which the authors are far away from presenting.

### Detailed comments:

1. The title is misleading since it gives the impression that the paper is on the health impact from anthropogenic aerosols. Only when reading the paper it gets clear that this study actually focuses entirely on health impacts from ship emissions.

2. The new method that is presented in this paper can be summarized in a single simple equation:

$$N_{deaths,total} = N_{deaths,cooling} + N_{deaths,exposure} \quad (1)$$

where  $N_{deaths,exposure}$  is the health impact due to aerosol exposure and  $N_{deaths,cooling} = \Delta T_{surface} * C$  is the number of lives saved by cooling from ship emissions; here  $C$  is a constant and  $\Delta T_{surface}$  is calculated from the radiative forcing (RF). All input variables in this equation ( $N_{deaths,exposure}$ ,  $C$ , and RF) are taken from the existing literature, picking a single study for each of them. I disagree with the authors that this equation is a qualified guess to estimate the combined health impact from aerosol exposure and climate. The equation is assuming direct and offsetting tradeoffs between the health impacts from a temperature change and from aerosol exposure. This seems difficult to support and argumentation why at least the authors think this is justifiable is entirely missing.

- Given the likely different populations that would suffer differently, and given that these estimates are statistical rather than identified as the same individuals, this seems to be incorrect methodology.
- The different timescales of health impacts due to these two different impacts are ignored, e.g. what is the timescale of the direct health effects? How long does it

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take before the effect has developed? How does this compare to the timescale of health effect through  $\Delta T$ ? Can the effects of these two fundamentally different mechanisms be added? The authors need to discuss this and need to extend their methodology to include the difference in timescales.

3. Except the back-of-the envelope calculation (that seems not to hold, see above) based on previously published results from other authors this paper does not present any new results. In addition, the authors ignore uncertainties in each of the two individual terms ( $N_{deaths,cooling}$  and  $N_{deaths,exposure}$ ) and neglect any non-linearities in the system that have been studied in much more sophisticated approaches elsewhere. Relevant articles that have been published on climate and health impact from shipping in the past years are not used and not even cited in this study. Rather the authors pick a single estimate from the literature for RF (*Fuglestedt et al., PNAS, 2008*) and a single estimate for health impacts (*Corbett et al., EST, 2007*).

- **RF from ship emissions:** (1.) a recent assessment by *Eyring et al., Atm Env.* (2009) showed that different estimates on the aerosol indirect effect yield very different results, ranging from  $-600 \text{ mWm}^{-2}$  to  $-66 \text{ mWm}^{-2}$ , depending on the method and ship emission inventory used. Here, the authors have used only the result from *Fuglestedt et al.* (2008). Global aerosol model results by *Lauer et al., ACP* (2007) and *Capaldo et al., Nature* (1999) calculate a much larger negative forcing. The uncertainty that arises from the range of RF calculated for the indirect aerosol effect from these different estimates needs to be considered. (2.) For the emissions that might be decreased by future regulations ( $SO_x$ ,  $NO_x$  and  $PM$ ) the authors use a RF of -0.11 (-0.07 to 0.16) from *Fuglestedt et al.* 2008. The RF is given without a unit and explanation is missing how these numbers have been derived from *Fuglestedt et al.* (2008). Did the authors sum up over individual RFs? This needs further explanation. (3.) Instead of using  $\Delta T = \lambda * RF$  which applies for equilibrium the authors could at least have used the  $\Delta T$  for the

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chosen year from *Skeie et al., Atm. Env. (2009)*. **(4.)** The geographical pattern of the temperature response due to a heterogeneous RF needs to be discussed (see *Fuglestedt et al., EST, 2009* and references therein). **(5.)** The authors account for uncertainty in RF but not in the number deaths per K. Both uncertainties need to be considered in the calculations, and not only discussed.

- **Health impact due to aerosol exposure:** *Winebrake et al., EST (2009)* quantified changes in premature mortality due to emissions from ships under several sulfur emissions control scenarios. The geospatial concentrations of pollutants attributed to shipping, including ship-induced  $PM_{2.5}$  that formed the basis for the health calculations, were calculated with a global atmospheric aerosol/chemistry model from the companion study by *Lauer et al., EST (2009)*. *Lauer et al.* calculated the impact on atmospheric aerosol burdens and the Earth's radiation budget under these low ship sulfur scenarios. One result was that the model showed that if emissions of nitrogen oxides ( $NO_x$ ) remain unabated, a reduction of the fuel sulfur content favors a strong increase in aerosol nitrate ( $NO_3$ ) which could counteract up to 20 percent of the decrease in sulfate mass achieved by sulfur emission reductions. These are important findings which are entirely ignored in this study. Rather the health impacts are taken from a single study that did not look at sulfur reductions.
- **Health impact due to climate change:** the authors need to discuss how climate change affects health. For example, are effects of extreme weather, precipitation, flooding, droughts etc included in the simplified equation? This does not seem to be the case and the method needs to be extended to include this.

4. Figure 1 shows a modified version of the radiative forcing figure from *IPCC (2007)*. It seems unnecessary to include this figure here. The  $SO_x$ ,  $NO_x$  and  $PM$  RF that is shown in the bottom of this figure is shown without error bar from a single study. However, the *Fuglestedt et al. (2008)* estimate for RF that is used here is only one

out of a few estimates that have been published in the literature in recent years, see above. This figure should be deleted.

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