Interactive comment on "The impact of ship emissions on air quality and human health in the Gothenburg area – Part I: 2012 emissions" by Lin Tang et al.

Reply to Reviewer 1:

The authors would like to thank to Reviewer 1 for a thorough review of the manuscript and for the constructive comments. Here are our responses:

1. *Line 35-36: Is this the summer mean or annual mean, please rephrase the sentence. Please provide relative contributions (%) along with absolute contributions*

Response:

It should be summer mean. The sentence has been rephrased as "The local shipping emissions of NOx led to a decrease of the summer mean O3 levels in the city by 0.5 ppb (~2%) in average."

2. *Line 157: "exposure-response function"*

Response:

The typo has been corrected

3. *Line 296: What is spatial resolution of the SMED database that is the source of these "other" emissions and how are they regraded into 1x1 km resolution? In addition, how are there emissions regridded to the TAPM resolution of 250 m?*

Response:

The spatial resolution of the SMED database is 1x1 km. The SMED gridded emissions for the different source categories were applied directly as gridded sources in the model.

4. *Section 2.2.2: Does road traffic includes resuspension so that it is the largest PM_{10} source in the domain?*

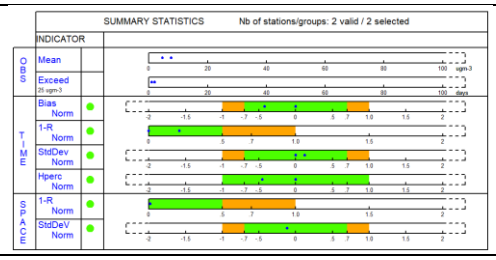
Response:

The road-traffic emissions include the wear particles, however, not the re-suspension. This fact has been added to the methods part.

5. *Section 2.4. Why no model evaluation for PM2.5? Section 3.2.4 includes some discussion on modelled vs measured PM2.5, why not include these in the model evaluation section? It is very important as PM2.5 is the main health impact pollutant and errors in PM2.5 simulations lead to underestimations in the health impacts.*

Response:

We would like to thank the reviewer for pointing out this omission. Model evaluation for $PM_{2.5}$ has been added to the text and Figure 5 extended with panel for summary statistics for $PM_{2.5}$. In addition, section on comparing measured versus modeled daily concentrations of NO_2, O_3, PM_{10} and $PM_{2.5}$ has been included in the supplement in response to a comment of Reviewer 2.

(c) ***$PM_{2.5}$*** At Femman and Haga	

6. *Section 2.5: Are the age intervals taken into account? If not, please discuss potential shortcomings. How are the chronic vs acute impacts taken into account?*

Response:

We would like to thank the reviewer for pointing out these deficiencies in description of the HIA methodology. Both aspect of the age intervals and form of the ERF for $PM_{2.5}$ have been added to Section 2.5:

ARP uses linear ERFs, recognizing the limited range of pollutant exposures in Europe. The YOLLs are calculated per year, applying the relative risk within national life tables. This is done through relation between life years lost per 100 000 population per unit $PM_{2.5}$ concentration and life expectancy of the population developed by Miller et al. (2003) based on analysis of life tables. The premature deaths are calculated using the total national mortality rate. This methodology is justified for European countries with health status and proportion of natural mortality of population corresponding to population studied in the epidemiological studies which brought forward the CRFs for all-cause mortalities. For regions with high concentration levels of $PM_{2.5}$ the HIA studies need to use different form of ERFs and for populations with different health status comparing to the US and Western Europe, cause-specific rather than all-cause mortalities need to be used.

7. Section 3.2. Please provide with relative contributions along with absolute contributions throughout the text.

Response:

The relative contributions were added for SO_2 concentrations (3.2.1), NO_2 (3.2.2.) and ozone (in Conclusions). For PM (3.2.4) the relative contributions were already presented.

8. *Section 5. How about the linearity of the ERF? There are studies clearly showing that assuming a linear relationship can lead to significant under or over estimation of health impacts depending on the concentration range. This should be discussed, I think.*

Response: The discussion on ERF model as well as on use of all-cause or cause-specific mortality ERFs was added to Section 5:

In ARP a linear form of ERFs is applied which is justified by a rather narrow interval of PM exposure levels in Europe. In terms of impact of the total exposure to $PM_{2.5}$ on natural mortality, the linear and log-linear form of the functions give similar results within the concentration range of 10–30 µg m^{-3}, the linear model giving slightly lower relative risks in this range and higher relative risks below and above (Ostro et. al., 2004). The $PM_{2.5}$ levels found in our study fall below 10 µg m^{-3}. For regions with high $PM_{2.5}$ levels different ERF models need to be applied and for HIA global studies or studies

in other regions bur Western Europe or North America also ERFs for cause-specific mortalities, rather than natural mortalities are usually used.

In terms of incremental effects, the impacts can differ substantially between the two models at different concentration levels. Sofiev et al. (2018) show difference in relative risks of cause-specific mortalities for different base concentrations, at 1 µg m^{-3} the log-linear model gives higher incremental relative risks than the linear model while at 5 and 10 µg m^{-3} levels the log-linear model gives lower incremental relative risks.

9. *Brandt et al., 2013 is not cited in the text.*

Response:

The reference has been deleted

10. *Figure 8 could be made similar to figure 11, showing the monthly means as it is a bit crowded as it is now. In addition, both figures could use stacked bars instead. Finally, it would be great to create a similar figure where it shows the contributions from other pollutants as "others", that can be split into local and outside of Gothenburg and Sweden if possible, as in Im et al., ACP, 2019.*

Response:

The Figure 8 as well as Figure 11 has been updated by showing the contributions to monthly mean NO_2 and $PM_{2.5}$ concentrations from local shipping, regional shipping, road traffic and others.

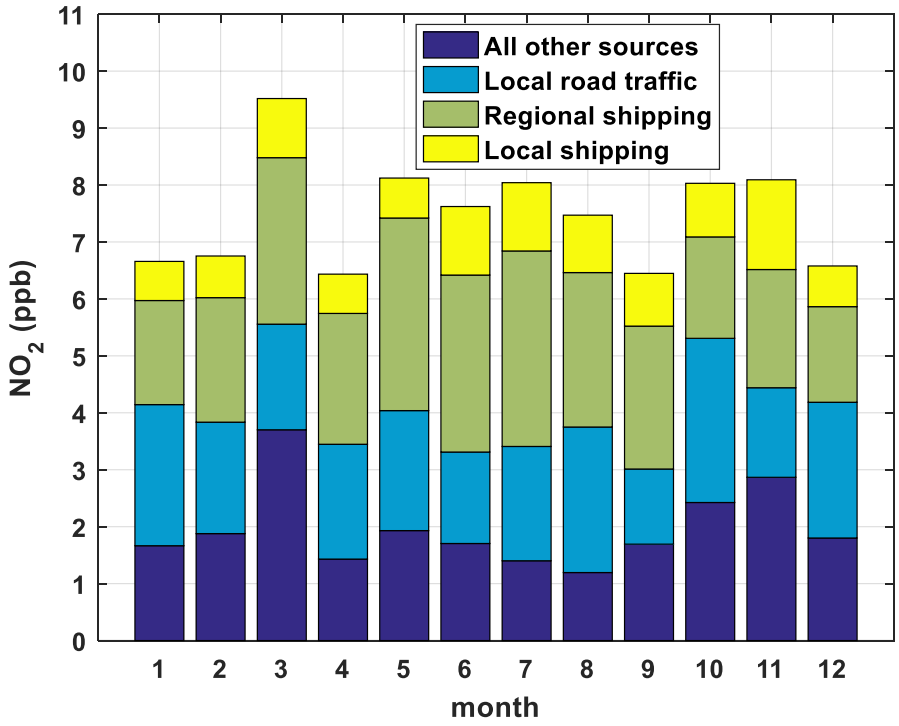


Figure 8: Modelled monthly mean contributions of the local shipping, regional shipping, local road traffic and other anthropogenic emissions (including contribution from the boundary conditions) to the NO2 concentrations (ppb) at Eriksberg in year 2012.