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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Effects of strengthening the Baltic Sea ECA regulations" *by* Jan Eiof Jonson et al.

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We, the authors, thank the reviewers for constructive comments and suggestions

Below we list the comments from reviewer 1 followed by our reply reference to any changes made in the paper.

Specific comments: 1. Page 3, line 10: Please specify what FMI stands for.

Answer: Finish Meteorologcal Institute now included in brackets.

2. Page 3, line 17: Here the ship emissions in daily temporal scale was first introduced, but later in line 30, it was mentioned that ship emission data in hourly temporal resolution was aggregated into monthly resolution in the CTM. Please clarify the original

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Discussion paper

temporal resolution of ship emissions and how it was implemented into the CTM.

Answer: The original temporal resolution is hourly. This is corrected in the text.

3. Page 3, line 18: What is the spatial resolution of ship emissions?

Answer: Spatial resolution for the ship emissions For the 2016 Baltic Sea emissions is about 0.034 x 0.018 degrees

For all other sea areas (2015) the spatial resolution is 0.09 x 0.089 degrees

The resolution of the ship emissions is finer than the model grid. Ship emissions are read into the model in the original spatial resolution and then interpolated to the model grid on the fly.

4. Page 3, line 24-29: The description of future emission projections for the year 2030 is not clear. Although it was mentioned some changes such as vessel size growth and fleet size increase, it will be helpful to include the exact or estimated percentage of ship size growth in 2030 compared to current ship size.

Answer: We now list the annual ship size growth used in the 2030 scenario compared to current ship size.

5. Page 4, line 18: I understand the authors mainly focused on the influence of ship emissions, so they presented their results by averaging the three meteorological years. However, some important messages were missing if they took this approach. For example, the changes of observed SO2 and associated PM2.5 species before and after stricter SECA regulation was applied, which is highly relevant to the title of this paper and has critical policy implication. I suggest the authors add the comparison of observation between years to the paragraphs where the Present_HiSulphur and Present_Base simulation was compared.

Answer: The comparisons of model calculations to observations are discussed in section 3.1, where also the Present_HiSulphur and Present_Base simulations are dis-

cussed.

6. Page 5, line 12: As it showed that the elevated PM2.5 by BAS shipping emissions are concentrated over the shipping routes and the coastal cities close to the routes, the location of the cities relative to major shipping routes is important. It will be helpful to include a map showing the geographic location of the sites in Table 1 and 2. Also a discussion about whether the sites close to major shipping route would have larger impact of ship emission can be included.

Answer: A map with the position of the measurement sites is now included in the appendix. In the text we also note that the sites close to major shipping routes (as Anholt and Raaoe) NO2 and SO2 measurements can only be reproduced in the Present_Base calculation.

7. Page 5, line 28: What are differences between your estimated contribution of PM2.5 by BAS shipping emissions and the estimation by Karl et al. (2019) that mentioned in page 2, line 24?8.

Answer: Unfortunately there is very little overlap in the stations (even though the AIRBASE dataset also includes the EMEP sites used in this publication. Although the model resolution is the same the Karl et al. calculations have been made with an older EMEP version. Furthermore also land based emissions are lower in 2016 compared to 2012, especially of SO2. In the present study there is a tendency for more underestimation of NO2 and comparable results for the other species.

Page 5, line 30: The results showed that ship emissions contributed more on PM2.5 concentrations when the ship emissions were assumed to be at 2014 levels. Does it imply the PM2.5 contribution in 2014 (before strict SECA) was mainly from SOx? What is the fraction of sulfate in the modeled PM2.5 in Present_HiSulphur and Base simulation? Do the ground observations of PM2.5 show higher fraction of sulfate in 2014 and decreased fraction of sulfate in 2016 after the strict SECA?

Answer: measured and model calculated SO4 is now tabulated in the paper. The fraction of SO4 in PM2.5 was higher in 2014, but it was not the main component in PM2.5.

9. Page 5, line 32: Here you compared the differences between Present_Base and Present_Noship for NO2 and PM2.5 at the measurement sites. As the magnitude of NO2 and PM2.5 are different (it is not appropriate to compare their difference directly) and it is hard to tell the differences by eyeballing the numbers, I suggest to have barplots over a map (i.e. every site has its relative difference of Base and Noship (Base minus Noship divided by Noship) for PM2.5 and NO2 presented by a barplot), if it would not be too messy on a map.

Answer We have tried this, but given the format of the maps and the plotting software at hand it turned out not to be feasible without compromising readability.

10. Page 5, line 34 & Page 6, line 1-2: It was stated that the model results underestimate the measurement at most of the sites listed. What is the criterion of evaluating Base model performance?

Answer: The criterion is based on the comparison to measurements. This is discussed in more detail in the EMEP model validation report from 2018 https://emep.int/publ/reports/2018/sup_Status_Report_1_2018.pdf comparing EMEP model results to measurements for 2016. We have included a reference to this publication, and some accompanying text, just before section 3.1 (Se also reply to reviewer 1.)

11. Page 6, line 33: This discussion would benefit from a quantitative indication than just describing the largest contribution are seen for smaller countries with long coastline. I suggest to add a quantitative assessment like the contribution weighted by coastline length or weighted by distance-to-major-shipping-route to strengthen the statement here.

Answer: We agree that a quantitative assessment like the contribution weighted by coast-line length or weighted by distance-to-major-shipping-route would have strengthened the statement. We have considered this. The length of the coastline, and the coast/area ratios for countries are available from several sources such as Wikipedia and wold.by.map.org, all listing virtually identical numbers. We are however uncertain whether the methods calculating the length of the coastlines are comparable between countries. As an example all sources list the coastline of Estonia as being longer than both the coastlines of Sweden and Finland. This is most likely due to different measurement techniques. Basing our conclusions on data that are not comparable would not be scientifically sound. We have also considered using distance-to-major-shipping-route as a criteria, but found it hard to define and calculate in practice.

12. Page 7, line 6: Figure 3b shows the reduction of NO2 caused by ship emission in 2030 (i.e. For each country, the green bar along with blue bar is shorter than the green bar with black bar). As it is stated here, the improvement of the pollution levels is caused by reduction of BAS ship emissions. However, in page 3, line 24-29, you mentioned increase of ship size and fleets, and in page 4, line 23, the future scenario was assumed with NECA (and strict SECA?) applied. How the vessel size growth and fleet size increase, which would lead to more emissions, are balanced with strict regulations to have emission reduction in the future?

Answer: The future scenarios will either add or subtract vessel activity of the base year (2014), depending on the fleet size growth rate. If currently there were 100 containerships and an annual growth rate of one percent is applied, then 143 ship would exist in 2050. Adding 43 containerships to the fleet is done by replicating the activity of 43 randomly chosen containerships which exist in 2014. Introducing 43 new ships will need to comply with the existing year 2050 regulations, like Tier III limits, if the vessels were younger than 29 years. The changes in physical dimensions of future ships their impact on vessel speed/resistance curves is not considered, however.

13. Page 7, line 21: It was stated that increase of SOMO35 is more than annually

averaged ozone. The units of SOMO35 and annually averaged ozone are different. What is the comparing criterion in this statement?

Answer: We have added the word relative. This statement was based on considering percentage increases (which are not shown). Relatively speaking the changes in SOMO35 are more pronounced. This is not uncommon for a threshold indicator, where many areas are just below the threshold in the base case.

14. Page 7, line 23 & line 24: It was explained the changes in SOMO35 and annually averaged ozone by combination effect of ozone enhancement in the summer and decrease during the winter time. It would be supportive to add analysis of separating SOMO35 and ozone difference by two seasons into appendix and references to support the argument.

Answer: We have included figures of summer and winter SOMO35 and average ozone in the appendix and the discussion of the results for average ozone and SOMO35 is extended referring to these figures.

15. Page 7, line 25: There are some confusion for the discussion here. In Figure 4,both Germany and Denmark show decrease of annual mean ozone in 2030 (Present-2030, positive difference), but the statement here is "the additional emissions from BAS shipping lead to 'reductions' in annual ozone in Denmark. Furthermore,..... result in 'increased' annual ozone levels in Germany." Conflict arises from the differences between discussion mentioned above and Figure 4.

Answer: This part of the paper is re-written, See below

16. Page 7, line 27: It is not clear in the discussion here. Figure 4 shows that the-SOMO35 increases in the future (also stated in Page 7, line 21) for the two cases, but the statement here – "Even though annual ozone..... lower emissions will result in SOMO35 'reductions' in both these two cases.....". – you mentioned 'reduction' in SOMO35 instead. Additionally, I didn't see the clear connection between SOMO35

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reduction and winter titration events.

Answer: We have now rewritten the text related to ozone and SOMO35. We have also included figures showing the winter and summer difference between the years 2030 and 2016 in ozone concentrations and SOMO35. We have have also added a reference corroborating our results.

Technical comments:

1. Page 7, line 9: It should be Figure 3e, instead of Figure 3d.2.

Answer: This is now fixed.

Page 7, line 19: Please rewrite the sentence, “Also show are the effects....”.3. Figure 1: Please add X-axis and Y-axis label of longitude and latitude and remove the remaining cut-off headers in the plots.

Answer: Regarding line 19, page 7. This part is rewritten, see answer to previous comments.

X and Y long and Lat labels are added and cut-off headers are removed.

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