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Atmospheric Chemistry and Physics Discussions

# *Interactive comment on* "Model calculations of the effects of present and future emissions of air pollutants from shipping in the Baltic Sea and the North Sea" *by* J. E. Jonson et al.

**J. E. Jonson et al.**

jan.eiof.jonson@met.no

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We would like to thank the reviewer Pieter Hammingh for taking the time to read our paper and giving us valuable comments. We have revised the paper by taking into account the reviewer's suggestions and provide responses to the individual comments below. In addition we have included some new material, comparing our results with previously published results.

**Specific comments:**



Page 21949, line 20
There are several factors which will have an impact on the quality of predictions of emissions from small vessel traffic. For example, incomplete representation of small vessel activity in AIS because AIS equipment is not installed or properly used will lead to incomplete representation of vessel activity. Already in Finland, there are over 195 000 small boats with a combustion engine and only a fraction of these are equipped with AIS equipment. For these crafts AIS equipment can be used but it is voluntary and requires a radio licence. Additional uncertainty is introduced when small vessel particulars have to be estimated. We have added the following text to Page 21949, starting from line 24:

"The IHS Fairplay database queries mostly cover vessels which have an IMO registry number. The database can be searched with a Mobile Maritime Service Identity (MMSI) number, too. However, in >90% of the cases MMSI queries do not produce a valid response because there is no obligation for small vessel to register in these databases, especially if they operate on national waters. It is often the case that small vessel particulars in STEAM are not known and default values for small vessel need to be used when engine power levels are predicted. Obviously, this will lead to deteriorated performance of emission model performance if compared with the quality of predictions for large vessels where engine data is more readily available."

FMI (Jalkanen and co-workers) is currently in the process of a revision concerning the treatment of small vessel emission calculations by incorporating vessel data from national boat registers, but this work requires considerable efforts and cannot be reported in this manuscript.

Some indication of the importance of small vessels to overall ship emissions can be found in Jalkanen et al (Ambio, 43, 2014, 311). Even if that study describes ship emissions in the Baltic Sea during 2006-2009, it can be concluded that small vessels' contribution to the overall fuel consumption is less than 15%. The contribution of small vessels to overall $SO_x$ and PM are bound to be less than this because small vessels

use distillate fuels which have less sulphur than the fuel used in large marine engines.

Page 21950: line 17-19:
The reviewer is correct. The ash content of marine fuel is regulated by ISO 8127 standard, which sets the upper limit for ash content in ship fuels. These are 0.01% (by mass) for distillate and 0.07% (by mass) for heavy fuels. In STEAM, ash emission factor corresponds to 0.03depending on specific fuel oil consumption) which is in between the values set by ISO 8127 standard. Regardless of the uncertainty of ash emission factors, the overall contribution to primary and/or secondary PM, beyond how they are described in the manuscript, is unlikely to change the conclusions concerning the health effect evaluation. We have modified this part of the manuscript (Page 21950, line 20:

"Emissions of organic and elemental carbon and ash also increase as they are assumed to be unaffected by the fuel type (Johansson et al., 2013). In reality, different amounts of ash in distillate (0.01 w-%) and residual fuels (0.07 w-%) are allowed as indicated by marine fuel standard (ISO 8127:2010; Chevron 2012). In STEAM, ash emission factor is 0.06 g/kWh which corresponds to 0.03-0.04% (by mass) depending on engine specific fuel oil consumption. The values used in STEAM for ash emission factors are similar to the results recently reported by Moldanova et al (2013) and more details of emission factors of PM components can be found in Jalkanen et al (2012).

The fuel mix used in 2011 was predicted as 74% of residual and 26% as distillates, based on the engine properties and the fuel consumption of currently operational vessels in the study area. The future adoption rate of LNG as ship fuel is difficult to predict, but it is expected to grow significantly in the future especially if new emission control areas for NOx are to be established. However, the NECA declaration of both the Baltic Sea and the North Sea is uncertain because it requires political consensus and the effective date of new NECAs are yet to be defined. We have applied the 2011 fuel mix until 2015 after which a shift towards distillate fuels is expected whereas LNG share



of marine fuels remained at 2011 level. This will have a slight impact on PM reduction prediction because it is likely that the adoption of LNG reduces PM more than the use of distillate fuels."

Page 21955, line 7:
Regarding NOx titration effects, in particular in the North Sea area, we have added the folowing section:

"Beekmann et al. (2010) performed detailed model calculations with projected emission changes, demonstrating a future transition from NMVOC-limited to $NO_x$-limited regimes in large parts of Europe north of the Alps, except in the region in and around the English Channel, which will continue to be NMVOC-limited at least until 2020. In NMVOC-limited regimes the production of ozone is controlled by the availability of NMVOC, while further enhancements of NOx there would lead to titration (and thus reduction) of ozone. In NOx limited regimes, increases in NOx will cause increased formation of ozone."

**Technical corrections:**

Page 21944, line 2 - 6:
Too many commas. Number of commas now reduced.

Page 21944, line 21:
Present changed to current

Page 21945, line 12:
Land based sourced specified.

Page 21945, line: 21:

From international shipping specified

Page 21945, line: 22:
Sentence restyled.

Page 21945, line: 27:
Decided changed to mandatory.

Page 21946, line: 1 - 2:
The starting dates of the Baltic Sea and North Sea SECAS specified.

Page 21946, line: 11 - 13:
The first sentence has been replaced with the following: $SO_x$ and PM emissions from North Sea and Baltic Sea shipping are decreasing, but it is noteworthy that there may be some components of PM from shipping that are not affected by the fuel sulphur content.

Page 21946, line: 18:
We have changed this too .... all sea areas around Europe ..... (Not all countries in the region are members of the EU)

Page 21946, line: 25 - 26:
Sentence removed.

Page 21946, line: 26:
Regarding the share of LNG. We have added the following text at the end of line 27: Future projections were done in accordance with Kalli et al (2012). In their work, old vessels are replaced with new ones at the end of their lifecycle. In this approach, the new vessel to be introduced in the fleet will comply with future legislation (NECA/not NECA as defined in the scenarios) but will not undergo liquid fuels to gaseous fu-



els transformation. We agree that this aspect of scenarios developed by Kalli et al should include LNG market penetration, especially because there are LNG infrastructure projects already underway and more are planned in the future. All existing vessels known to use LNG will continue to do so even when they are replaced with new vessels in the scenarios.

Page 21946, line: 29:
Regarding TIER II reductions, this sentence now reads: Defining a NECA (Nitrogen Emission Control Area) for both the Baltic Sea and the North Sea will help to reduce the emissions of $NO_x$ by as much as 80% from Tier I level on new ships.

Page 21947, line: 21:
The sentence has been rephrased.

Page 21947, line: 27:
High temporal and spatial resolution is now specified.

Page 21948, line: 13 - 14:
The scaling is based on the measurements specifically from the clean sector at Mace Head. This is described in Simpson et al. (2012).

Page 21948, line: 16:
We haveadded some text, with references, at the end of this section egarding meterology and pollution levels in 2010 compared to the long term trend. "The meteorological year 2010 was used in all the model calculations. The 2010 winter was colder and dryer than normal north of the Alps, and the cold weather returned towards the end of the year. The summer was very warm, in particular in Russia extending into the Baltic Sea (Maier et al. 2011). The warm summer resulted in higher than normal ozone levels around the Baltic Sea (Fagerli et al. 2012). The cold and dry winter resulted in PM2.5 and PM10 concentrations somewhat higher than expected from the long term trend

alone (Tsyro et al. 2012)."

Page 21949, line 2 - 5:
The EC4MACS emissions are used for land based emissions, but also for sea areas other than the Baltic Sea and the North Sea. This is now specified in the text: "The emissions include both land based and emissions and emissions from international shipping."

Page 21949, line 26:
The ship emissions are agregated to the model grid. This is now stated a few lines below (what was) line 26.

Page 21950, line 20:
See specific comment for Page 21950, lines 17 - 19.

Page 21951, line 2:
The emissions of $SO_4$, OC, EC and ash add up to the total primary $PM_{2.5}$ emission. It should be straight forward for the reader to add these if needed.

Page 21951, line 2 - 10:
English editting: The text has been changed: "It is uncertain when, or if, the two areas will be designated as NECAs. If so, ships built after NECA designation date will be Tier III compliant. As the designation of NECAs is still uncertain, $NO_x$ emissions for year 2030 are listed with and without a NECA, assuming an entry date of 2016. A complete fleet renewal is slow, and can be expected about 30 years from the NECA entry date. The implementation of the NECA may be delayed, as agreed in the 66th meeting of the IMO MEPC. A delay will result in higher 2030 $NO_x$ emissions in the NECA than indicated in Table 1..

Page 21952, line 12 - 14:



Regarding the relationship between YOLL per country and LLE we have added this explanation: "The accumulated YOLL per country is calculated as the product of YOLL per person and the population in the individual grid cells, and then summed up for the individual countries."

Page 21952, line 18:
Assumed changed to used.

Page 21952, line 19:
Assumptions changed to dose response relationships.

Page 21953, line 28:
We have added: " ... as most of the PM from shipping is SIA (Secondary Inorganic Aerosols), or has been emitted with a particle size below 2.5$\mu g\, m^{-3}$."

Page 21956, line 19:
Added: ... in terms of emission schanges.

Page 21956, line 22:
Added: ... land and sea based emissions

Page 21957, line 22 - 23:
We have now specified in the text that the nitrates are formed from $NO_x$.

Page 21958, line 1:
We have added that the strengthening of the regulations refers to sulphur

Page 21958, line 6:
Foreseaable corrected to forseeable

Page 21958, line 7:
This sentence has been changed to: "The transition to TIER II on new ships, and new-build ships becoming more efficient, will help stabilise $NO_x$ emissions from shipping."

Page 21958, line 17 - 19:
We have now distinguished between distillate and non distillate fuels in the text: This sentence now reads: "The use of low sulphur distillate fuel (0.1 %) or the use of alternative fuels or scrubbers are expected to increase fuel costs by 30–80 % compared to marine fuels with 1.5 % sulphur content."

Page 21964, Table 3:
Oxidised nitrogen given as N (molecular weight of N). We have changed of N to as N in the table caption.

Page 21970, Figure 4
Subscripting of PM2.5 and space between units. This comment also affects the style in Figures 1,2,4,6,7,8. New versions of these figured have been made.

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Interactive comment on Atmos. Chem. Phys. Discuss., 14, 21943, 2014.