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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The impact of shipping emissions on air pollution in the Greater North Sea region – Part 1: Current emissions and concentrations" *by* A. Aulinger et al.

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General comments:

R: The language should be improved. Some suggested improvements are given in the detailed comments below. Still, the authors should carefully read through the text and improve the language. Some suggestions for improvements are included below. I confess that the motivation to comment on language has decreased towards the end of the paper.

A: The language was improved.

R: A large part of the manuscript describes the methods used to calculate the emissions from North Sea shipping. Several previous estimates of North Sea shipping have been made. A Table comparing the emission estimates from this work to previous studies (in addition to EMEP/CEIP) should be easy to include (Emission estimates from Jalkanen et al, EMEP, Hammingh et al. (2012) etc.). Hammingh et al. also gives a lower estimate of ship emissions in the North Sea than EMEP (and Jalkanen et al. (2012)). They ascribe the difference in their estimates to different assumptions for axillary engines. Please comment.

A: We added the demanded table. Due to the many uncertainties, concerning for example the identification of ships from AIS signals, gaps in the ship characteristics data base, external effects like wind or fouling and of course the power and operation modes of auxiliary engines, ship emission inventories bear certainly sizable uncertainties. Hammingh et al. mention in their report that the main part of the 38% difference to the emissions of the STEAM2 model is due to auxiliary engines, the exact number is not given. Our estimations about the error margins introduced by not knowing the operation mode for auxiliary engines at sea are 4% (see also our replies to reviewer 1). However, this does not cover the uncertainties caused by not knowing the exact engine power of auxiliary engines and 4% may still be too little underestimation. Yet, we don't see an indication that the uncertainties concerning auxiliary engines account for the total difference. In section 2.3 we describe our workaround for missing entries in the vessel data base. To investigate the differences between the models and inventories in detail is out of the scope of our study.

R: Ship Emissions are representative for year 2011 (post SECA) whereas the meteorology and air pollution measurements are from 2008. The Recession started in 2008 (but full effect not until 2009?). Much of the effects of the recession had recovered by 2011. This should at least be mentioned/discussed.

A: We mention this now in the introduction.

R: In large parts of the North Sea region ozone is NMVOC limited with titration controlling ozone levels much of the year, see for instance Beekmann et al. (2010). This makes the calculation of the effects of ship emissions on ozone levels a challenge. Please comment.

A: It is discussed in section 5.2.3 that depending on the presence of (NM)VOC increased NOx from ships can either lead to an increase or decrease of ozone concentrations.

R: I can not find any information on the horizontal and vertical resolution for the CMAQ chemical tracer model.

A: It is added in the model description now.

R: Furthermore, the model calculated ozone levels are overestimated, at some sites by as much as 10 ppb. Why? Could it be that your boundary levels (from TM5) are too high? Is there a particular season when the overestimation is larger? Regional models usually perform remarkably well for ozone (see for instance Solazzo et al. (2012) where the CMAQ model is also included).

A: On average, the model overestimates ozone by approximately 5% in this study, even if it is more at some stations. This lies within the variation of the ensemble data evaluated by Solazzo et al. (2012).

Detailed comments:

Page 11278, line 20 Based on the information later in the manuscript The total emission from shipping is from the North Sea plus some additional sea area west of the North Sea?

A: We added this information.

Page 11279, line 12 .... the North Sea is accepted as an (not accounted)

A: We use now the verb designate.

Page 11279, line 15 You should also mention that from January 2010 the EU sulphur directive requires ships to use fuel with 0.1% or less in EU harbours.

A: This is now mentioned in the introduction.

Page 11279, line 22 You should add ozone to the list of secondary pollutants.

A: We mention now also ozone as secondary pollutant.

Page 11282, line 8 Delete used and set up: ... required by the chemistry transport model.

A: We disagree because the resolution of the emission inventory doesn't depend on the CTM in general but on the set-up chosen.

Page 11282, line 9 AT open sea

A: We would like to keep "on the open sea".

Page 11282, line 10 - 11 Difficult sentence to understand.

A: We would like to keep the sentence as it is.

Page 11282, line 16 generate instead of elaborate.

A: We would like to keep elaborate.

Page 11283, line 6 the resulting tracks were rejected

A: We use "detected" because this sentence describes the criteria by which erroneous signals were detected. The following sentence describes that we deleted these signals from the ship track.

Page 11284, line 3 - 6 Incomprehensible sentence. Please rephrase.

A: We changed this into "In cases where the same IMO number corresponded to more than one MMSI number, the most frequently found pair was chosen to identify the IMO number of a vessel."

Page 11284, line 9 ... (Table1) were collected from the ship

A: We changed this into “selected”.

Page 11284, line 13 Emissions from all vessels

A: The procedural step described here was to divide the vessels not the emissions.

Page 11285, line 6 - 7 It is unfortunate that emissions from mooring was not included in the database.

A: We agree. Please refer to our reply to reviewer 1 on this point.

Page 11285, line 16 I did not quite understand what it means that the axillary engine load was 0.3. Please explain.

A: Keeping it constant was how auxiliary engine operation was treated in the model. This follows a suggestion by Whall. A reference given in the text now.

Page 11286, line 13 - 17 Here ship emissions are aggregated to a specific model domain. As I understand data funded by Interreg projects should be free to use. Is the dataset available and transferable to other resolutions/projections? If so you should state so.

A: The inventory is available as netCDF files. It is mentioned now in the acknowledgements.

Page 11286, line 22 A ship is sailing, not travelling (even when using an engine). See also next page.

A: We changed this into “sailing”.

Page 11287, line 2 What is meant by in general?

A: We meant by all ships, not distinguishing between engine types. This section was rewritten, however.

Page 11287, line 3 calculated for (use assuming instead of for)

A: We changed this into “assuming”.

Page 11287, line 19 - 22 Please rephrase.

A: The sentence was changed into: Table 2 shows the share of ships of different sizes concerning total fuel consumption, NOx and SO2 emissions on the North Sea.

Page 11288 Line 3 - 4 lower, (not less) higher (not more)

A: We changed the wording as suggested.

Page 11288, line 10 I don’t understand the origin of the percentage difference. By high sulphur fuel you mean fuel content of more than 1% sulphur, or a lower percentage?

A: We mean 1% within SECA. It was added to the text. MDO has 0.2%, which is explained in the new emission factor section 2.4.

Page 11288, line 19 - 20 See comment, Page 11278, line 20

A: We added this information.

Page 11289, line 20 Here you should include something on NOx versus NMVOC control.

A: We explain this interaction in section 5.2.3.

Page 11289, line 21 - 22 PM is also emitted directly, see top page 11285.

A: This sentence is meant to stress the chemical part of the CTM, which is responsible for the formation of secondary particulate matter. Emissions mechanisms of PM is described in section 2.4.

Page 11289, line 23 - 25 You should also provide a reference to your land based emissions (what is official European emission inventories). What about emissions from other sea areas as the western part of the Baltic Sea? Please also make it perfectly

clear that in the ship sensitivity model run ship emissions are removed only for the North Sea (+ a small additional part of the eastern North Atlantic?)

A: The officially reported emissions are available through the CEIP web page, which is referenced now in the text. Ship emissions from outside our model area are also taken from CEIP. This is also mentioned in the text now. In the sensitivity run, there are no ship emissions at all.

Page 11291, line 20 - 23 Contrary to NO2, land based emissions of SO2 are mainly from relatively few large point sources with variable stack height. How are these large point sources treated in the model?

A: The treatment of land based emissions is described in the reference given (Bieser et al.; SMOKE-EU). We think it would lead to far to explain this here.

Page 11292, line 1 SO4 (sulphuric acid is also emitted directly, see top page 11285.

A: We added “Only about 5% of the fuel sulfur is emitted as sulfuric acid aerosol whereas most of the particulate sulfate is produced in the atmosphere from SO2” to this paragraph.

Page 11292, line 16 - 18 Please rephrase.

A: We split the sentence into two.

Page 11293, line 14 - 15 Should it be western rather than the eastern part of the Baltic Sea?

A: Indeed!

Page 11294, line 14 .... much smaller increases were calculated along

A: Changed as suggested.

Page 11294, line 23 These pollutants have a relatively short residence time in the atmosphere and are removed by dry and wet deposition.

A: After the sentence “ The reason is that pollutant plumes from the shipping lanes passing the Channel are transported towards the continent by the prevailing westerly and south-westerly wind directions.” we added “ During this transport, they are partly removed from the atmosphere by wet and dry deposition.”

Page 11295, line 1 Here, not there.

A: Changed as suggested.

Page 11295, line 8 .... to those of moderately polluted regions .....

A: Changed as suggested.

Page 11295, line 12 - 13 This sentence is hard to read. Please simplify.

A: We added a comma.

Page 11295, line 22 From Figure 2 I get the impression that ship emissions peak in summer.

A: That’s true. We changed this sentence in “...while the shipping activity is only slightly higher in summer, significantly...”

Page 11296, line 1 Surely you only mean the western border here?

A: Yes, we added “northern and western”.

Page 11296, line 13 Pollutant plumes, not clouds

A: Changed as suggested.

Page 11296, line 8 - 16 Please rephrase this sentence. Furthermore, ammonia emissions have a strong seasonal variation. The dry deposition of gaseous HNO3 is much faster than for ammonium nitrate. The removal of total nitrate (gaseous HNO3 + particulate nitrate) should then depend on the availability of ammonium.

A: We added “Furthermore, ammonia emissions are lower in winter, which additionally

limits the formation of ammonium nitrate and enhances the dry deposition of gaseous nitric acid. The latter, however, has no effect on ammonium sulfate because in ammonia limited conditions the ammonium sulfate production is preferred over ammonium nitrate production." to the end of this paragraph.

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 11277, 2015.