

Interactive comment on “Multi-model simulations of the impact of international shipping on atmospheric chemistry and climate in 2000 and 2030” by V. Eyring et al.

Anonymous Referee #1

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General comments:

The manuscript is generally well written and structured. It addresses the impact of ship emissions on atmospheric chemistry and climate, a topic which is currently in discussion as an important source of current and future emissions. Some approaches of the manuscript are not quite clear and some might limit the conclusions that can be drawn from the manuscript, see paragraphs below. Before the manuscript can be accepted for publication, these issues need to be considered in the revision.

For what reason only NO_x and SO_x emissions from ships have been considered? What about NMHC and CO emissions from ship traffic? In Eyring et al. (2005) these

emissions are specified and in the atmospheric models they can be included straightforward. The reference to Endresen et al. (2003) on page 8562 as a paper that showed that the effects of CH₄ and NMHC emissions from ships on ozone are very small seems not convincing. In the abstract of that paper it is written that ozone perturbation by ship emissions are highly non-linear, being most efficient in regions of low background pollution. Neglecting CO and NMHC emissions from ships presents a crude simplification, which limits also the importance of the outcome and conclusion of the model exercise, e.g. that ozone concentration increases almost linear with NO_x emissions from ships. Is this an effect of neglected VOC photochemistry? Or is photochemistry taking place only in the NO_x sensitive regime at low NO_x concentrations (see Sillman et al., JGR 1990).

Plume chemistry: photochemical reactions and aerosol microphysical modifications in high concentrated air parcels do not only take place in ship emission plumes, but close to all natural and anthropogenic point and area sources, and are therefore a general issue in atmospheric chemistry modeling, if the horizontal resolution is higher than a few meters. In addition local deposition close to the sources is an issue of uncertainty. The discussion on page 8557 and in section 4.1.2. could therefore be omitted or should be presented in a much more general context.

In the abstract it is mentioned that future NO_x scales almost linearly with increases of NO_x emissions totals -> what about NO_y, e.g. HNO₃, PAN? There seem to be not much non-linearities in photochemistry happening in the models. For the assessment of the impact on ship emissions on atmospheric chemistry and radiative forcing an approach that takes the non-linearities in photochemistry into account is to mark specific trace species, as it has been done e.g. for SO_x in Marmer and Langmann (Atmos. Environ. 2005), who studied the effect of ship emissions in the Mediterranean area. Resulting increase and decrease of secondary trace species like sulfate or ozone due to emission reduction or increase is shown not to scale linear. Could you comment on that, also with respect to section 4.2. Results in the context of other emission scenar-

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ios?

Emphasizing the ship emission effects in the Baltic Sea region is somewhat misleading. It should be pointed out in the manuscript that due to the used ship emissions inventory the effects in the Baltic Sea region might be overestimated. Other uncertainties are also mentioned repeatedly in the respective context, this should be also done for the effects in the Baltic Sea area, e.g. on page 8562 in connection with Fig. 1. Does the coarse model resolution limit the outcome of the model simulation for small areas like the Baltic Sea or Red Sea? And in comparison to Mediterranean ship emissions the Baltic Sea emissions seem to be rather large, whereas they are unrealistically low at the British Cannel. Over Europe a comparison with EMEP emissions might be helpful.

The only model evaluations shown and discussed is that with SCIAMACHY data in Figure 4. In particular over Europe long term time series from the EMEP stations are available. These or other observation data from e.g. field campaigns should be used to evaluate the ensemble mean model simulation results for 2000 in particular over Northern Europe. Such comparisons help to evaluate the uncertainties and limitations of the model exercise so that impacts of the results can be related better to the real atmosphere rather than only the model world.

Section 3.2.2. is not written very clear, neither the motivation to find a linear relationship nor the description of the results in particular of Fig. 7. Figure 6 should go into Figure 8, the motivation to derive a linear relationship for non-linear photochemistry should be given in the context of neglected VOC and CO emissions from ships and the paragraph needs to be rewritten. What is meant with O3 saturation effects and where should these be visible in Fig. 7?

Specific comments:

Abstract:

- Mentioning of the anthropogenic emissions (page 8555, line 29) already before (page

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8555, line 8)

- A statement of the importance of the effect from ship emissions on climate and air pollution relative to other sources is missing.

- NO_x enhances OH? Simplification -> isopleth diagram

- IPCC SRES A2 not explained, avoid abbreviation in the abstract

1. Introduction:

-international shipping: some explanation or definition would be helpful, e.g. are harbour emissions included?

- It should be mentioned that also BC and OC aerosols from ship emissions impact on climate

- The missing NMHC and CO emissions should be mentioned

- Page 8557, line 2: too strong statement: \ddot{E} models overestimate the observed NO_x distribution for example over the Atlantic, but underestimate SO₂ observations. This sentence is misleading without further explanation and out of context, because it is not generally true.

- Page 8557, line 6: again too strong statement, better: one possibility for the discrepancy between measured and modelled \ddot{E}

- Page 8557: SO₂ is not at all independent on plume chemistry. Chimney emissions from fossil fuel burning contain enough water vapour that condenses pretty fast and present an ideal environment for aqueous phase reactions, e.g. SO₂ oxidation in particular in the humid marine boundary layer. Sulfate formation and the indirect aerosol effect mentioned in the next sentence of the paper prove that.

- Page 8558, line 10: what is meant by ship modifications? Here it could be mentioned that ship engine are usually much longer in use than car engines are and therefore of

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old technology.

- Page 8558, line 22: needs to be: too strong, better: which can be
- Page 8559, line 13: add roughly: RFs due to CO₂ and sulphate are roughly estimated

2. Models and model simulations

- Page 8560, line 11 paragraph: in addition dry and wet deposition, vertical and horizontal diffusion and transport in convective clouds are treated different in the models; mentioned later on page 8564/8565, could be deleted there and mentioned here
- CO emissions from ships small? Why?
- page 8563: what is the additional available information to interpolate up to 5°x5° data to 0.5°x0.5° data?

3. Results

- Page 8564, line 15: slightly different background emissions? What is meant? Do the models not use the same emissions inventories for anthropogenic and natural emissions? If not, a reference to another paper is not sufficient, some explanation in section 2.2 is necessary.
- Page 8564, line 18: 'Previous studies reported that the production of ozone depends on the resolution of the model with models having higher resolution simulating less ozone production than those with a coarser resolution.' This statement is out of context and not at all right in general.
- Page 8565, first paragraph: the statement on the importance of ship emissions in the zonal mean related to 'background' value is missing
- Page 8565, from line 25: 'In July NO₂ changes are in general slightly smaller than in January and cover a smaller area Ě'. This holds only for the Baltic Sea region and the adjacent countries. Here the uncertainties of the emission inventory need to be

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mentioned. In the following sentences it is not clear what is meant with high NO₂ background concentrations over the Baltic Sea, they seem to be due to the coarse model resolution, but do not reproduce what is observed. Comparison with measurement data, e.g. station measurement from EMEP would be helpful. Mention uncertainties, like that shipping on the frozen Baltic Sea in winter time is overestimated due to the yearly average emissions inventory and put the importance of the results into a more realistic picture.

-Page 8568, line 25: 'Over Northern Europe \ddot{E} relatively low levels of insolation (even during summer)'. If the hours of sunshine are meant, than the sentence is certainly not right.

- Page 8571, line 5: replace oxidised by oxidation

- Page 8571, line 10: \ddot{E} such as sea salt, BC or OC \ddot{E}

- Page 8571, first paragraph: too much introduction, either leave it out or add it somehow to section 1: Introduction

- Page 8571, second paragraph: mention that zonal means are presented

- Page 8572, line 5: 'In all other parts of the world, changes in sulphate due to emissions from shipping remain low in general'. Again the uncertainties of this result should be mentioned, a potential overestimation of the Baltic Sea effect and a potential underestimation of the Mediterranean effect, where dry weather conditions favour the accumulation of 'pollutants' during summer.

- Section 3.4, first paragraph: rather unclear, either more explanations (e.g. wavelength intervals considered, how are clouds considered, what is meant by stratospheric temperature adjustment, what means instantaneous in this context?) of the off-line radiative transfer model are necessary or all details should be skipped. The reference to Edwards and Slingo (1996) is missing in the reference list. Avoid the word 'code', which is rather technical.

- Page 8574: first paragraph, last two sentences: not clear without more explanation; unnecessary, can be deleted

4. Discussion

- Page 8575, first sentence: add NO_x and SO_x and for 2030 emission conditions without considering possible change in atmospheric temperature, dynamics, humidity etc.

- Page 8577, first paragraph: discuss the use of NO_x and SO_x ship emissions only without CO and NHMC emissions from ships on the oxidizing capacity of the atmosphere

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