Atmos. Chem. Phys. Discuss., 7, S4795–S4803, 2007
www.atmos-chem-phys-discuss.net/7/S4795/2007/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global model simulations of the impact of ocean-going ships onaerosols, clouds, and the radiation budget" *by* A. Lauer et al.

A. Lauer et al.

Received and published: 7 September 2007

Reply to anonymous referee #1

We thank referee #1 for the work on the review and the comments on our manuscript, helping us to improve our paper.

General comments

1. Add global maps of the cloud droplet number concentration and cloud droplet effective radius at the boundary layer in Section 3.4. Their information is very important

for readers to understand the aerosol indirect effect described in Chapter 4.

We followed the suggestion of the reviewer and included a figure showing annual average cloud droplet number concentration and cloud droplet effective radius in Sect. 3.4 (Fig. 5). The figure depicts the geographical distribution of these two parameters for the model level centered around 0.8 km (0.6-1.1 km), which is compared to satellite data in this section.

2. The method of deriving the aerosol direct forcing under the all-sky condition is inappropriate described at the last paragraph in Section 4.1. It has to be calculated from the clear-sky forcing AND cloudy-sky forcing with weighted by the cloud fraction at each time step in the simulation and then averaged. Recalculate it because estimating the aerosol radiative forcing quantitatively is meaningful for this study. The direct radiative forcing of the radiatively-absorbing aerosols, such as black carbon which is included in this study, strongly depends on relative altitude beween aerosols and clouds (e.g., Haywood and Ramaswamy, J. Geophys. Res., 1998; Takemura et al., J. Climate, 2002). The forcing even of non-absorbing aerosols, such as sulfate, depends on the liquid/ice water content as well as the cloud fraction. The estimation by Equation (1) is too rough, and the last sentence of Section 4.1 is wrong.

Because of the reviewer's concerns regarding our approximation for the calculation of the direct aerosol effect, we decided to run each of the 4 model experiments (inventory A, B, C, and without ship emissions) again. In these new model experiments, the radiation scheme is called twice, with and without taking into account aerosols. The difference between the two radiation calculations is the signal from the direct aerosol effect, which now can be calculated for all-sky conditions. We revised the corresponding paragraph of Sect. 4.1 accordingly and removed our approximation to assess the direct aerosol effect:

ACPD
7, S4795–S4803, 2007

EGU

"Small changes in cloud properties such as liquid water content, cloud droplet effective radius, or cloud cover between the model experiments with and without ship emissions are introduced not only because meteorology of each GCM simulation is not completely identical (random), but also because of modifications of cloud microphysical properties by ship emissions (systematic). These differences in cloud properties change the cloudy-sky ToA shortwave radiation even for identical aerosols. Thus, the calculated all-sky direct aerosol forcing results not only from changes in aerosol properties due to shipping, but also from different cloud properties. This prevents full separation of the direct and indirect effect, which makes a comparison of the direct aerosol effect calculated for the different ship emission inventories difficult. The all-sky direct aerosol forcing in each model simulation is calculated from the differences in the ToA all-sky solar radiation fluxes obtained with and without aerosols by calling the radiation module of the GCM twice. According to our model results, we estimate the direct aerosol forcing from shipping to amount $-0.011\,\mathrm{W/m^2}$ (A,B) to $-0.013\,\mathrm{W/m^2}$ (C). The differences in the direct aerosol forcing (all-sky) between the three ship emission inventories are smaller than expected from the emission totals (Tab. 1). This clearly indicates that the geographic distribution of the emissions plays a key role for the impact of ship emissions on the radition budget. Table 4 summarizes the direct aerosol forcing from shipping calculated for the three emission inventories."

3. The authors have to check English. There are a lot of mistakes in grammar (some of them are mentioned in Minor revisions), and therefore it is illegible. Writing legible manuscript is duty of authors. Let native speakers check English.

We went through the manuscript and improved our English. All changes suggested by the reviewer mentioned in the Specific comments have been implemented. In addition, we followed the suggstions given by a native speaker who was willing to read our article with special emphasis on the abstract and the conclusions.

ACPD
7, S4795–S4803, 2007

Specific comments

Page 9420, Line 6: Revise "... by scattering and absorbing incoming solar radiation ..." to "... by scattering and absorbing the solar and thermal radiation ...".

Changed as suggested.

Page 9420, Line 8: Revise "... cloud microphysics, to show that ..." to "... cloud microphysics. The simulation shows that ...".

Changed as suggested.

Page 9420, Line 15: Add "on the global mean" after "in the year 2000".

Done.

Page 9420, Line 22: Revise "... a change of the net top of the atmosphere (ToA) clear sky radiation of about ..." to "... a change in the net radiation budget at the top of the atmosphere (ToA) under the clear-sky condition of about ...".

Done.

Page 9420, Line 24: Revise the values of all-sky forcing according to the comment 2 mentioned above.

Done (see reply to 2nd point of General comments).

Page 9420, Line 26: Revise "(change of the top of the atmosphere shortwave radiative flux)" to "(a change in the atmospheric shortwave radiative flux at ToA)".

ACPD
7, S4795–S4803, 2007

EGU

Changed as suggested.

Page 9421, Line 12: Revise "... by scattering and absorbing incoming solar radiation ..." to "by scattering and absorbing the solar and thermal radiation ...".

Changed as suggested.

Page 9421, Line 15: Delete ", known as indirect aerosol effect" because a word "indirectly" appears in the previous sentence.

Changed as suggested.

Page 9421, Line 19: The authors should refer old papers on ship tracks from satellites, e.g., Nakajima and Nakajima (J. Atmos. Sci., 1995).

Following the suggestion of the reviewer, we removed "Schreier et al. (2007)" and added the following two references: Conover, J. Atmos. Sci. (1966), Nakajima and Nakajima, J. Atmos. Sci. (1995).

Page 9422, Line 4: Add "by ship emissions" after "the indirect effect".

Done.

Page 9422, Line 22: Revise "effect" to "effects".

Done.

Page 9423, Line 17: Revise "gas/-particle" to "gas/particle".

ACPD

7, S4795–S4803, 2007

Done.

1st paragraph in Section 2.2: Do the authors use an ocean model or only an atmospheric model with prescribed data of SST and sea ice? Describe clearly. If the latter, add a explanation of the prescribed data of SST and sea ice. The results largely change whether the ocean model is coupled or not.

We use an atmospheric model with prescribed SST and sea ice coverage. Both, SST and sea ice coverage are taken from the operational analysis data from ECMWF. We added the following sentence to Sect. 2.2:

"Sea surface temperature (SST) and sea ice coverage are prescribed according to the ECMWF operational analysis data, which are based on data products from the National Centers for Environmental Prediction (NCEP)."

Page 9424, Line 18: Revise "under year 2000 conditions" to "under the year 2000 condition".

We revised the sentence.

Page 9425, Line 6: Revise "with emission totals" to "with the SO_2 emission totals".

Done.

Page 9425, Line 8: Add "SO_2" after "9.4 Tg".

Done.

ACPD

7, S4795–S4803, 2007

Page 9426, Line 7: Revise "suggest" to "suggested" or "suggests".

Done.

Page 9426, Line 23: Revise "inventory B and C" to "inventories B and C".

Done.

Page 9432, Line 17: Add "(Table 2)" after "from shipping". 3rd paragraph in Section 4.1: Add a table on the shortwave radiative forcing of the aerosol direct effect from shipping in the Pacific, Atlantic and global mean as same as Table 4. To show it clearly with the table is useful for other researchers.

We added a new table on the direct aerosol forcing from shipping analogous to old Tab. 4 (new Tab. 4).

2nd paragraph in Section 4.2: Add a table on changes and changing rates in the cloud droplet number concentrations and cloud droplet effective radius in the Pacific, Atlantic and global mean. To show it clearly with the table is useful for other researchers.

We added a new table on the changes in CDNC and cloud droplet effective radius due to emissions from shipping as suggested by the reviewer (Tab. 5).

Page 9436, Line 11: Revise "whole sky" to "all-sky".

Changed as suggested.

ACPD

7, S4795–S4803, 2007

Page 9437, Line 24: Add "(Figure 11)" after "carbon dioxide and ozone".

Done.

Page 9438, Line 10: Explain a difference clearly in the radiative forcing between this study and "ship tracks" in Schreier et al. (2006).

To clarify the difference between this study and ship tracks in Schreier et al. (2006), we added the following paragraph to Sect. 4.3:

"Ship tracks are changes in cloud reflectance due to ship emissions, which are detectable in satellite data and are identified by elongated structures. In contrast, this study investigates in particular the large scale effects of ship emissions on clouds, after for instance SO_2 is oxidized to sulfate and emissions are spread out far over the ocean, which are not covered by an investigation of pure ship tracks."

Page 9438, Line 28: Add a value of RF from aircraft by Sausen et al. (2005).

We added the following statement to the corresponding sentence in Sect. 4.3:

"..., ranging between 0.048 and 0.071 W/m^2 (without cirrus) and 0.03 W/m^2 (0.01-0.08 W/m^2) for aviation-induced cirrus (Sausen et al., 2005)."

Page 9439, Line 11: Revise "the general circulation model" to "the atmospheric general circulation model" if without an ocean model.

Changed to "atmospheric general circulation model".

Page 9441, Line 12: Add a ratio of "from -0.19 W/m^2 to -0.6 W/m^2" to the total

ACPD

7, S4795–S4803, 2007

aerosol indirect effect.

The relative contributions of the indirect effects due to shipping to the total anthropogenic indirect effects are discussed a few lines below. In our opinion, an additional reference would therefore be redundant.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 9419, 2007.