Response to Referee #1

We are grateful to the anonymous Referee #1 for his/her very constructive comments, which helped us to substantially improve the manuscript. Detailed response is given below.

To address one of the reviewer's major concerns (general structure and readability of the paper), we restructured the manuscript as follows:

- The Model description and evaluation section has been moved to Appendix A. The model is now shortly introduced at the beginning of Section 3 (“Model simulations”) and readers interested in more details are referred to the Appendix.
- The description of the various size distributions assumed for each sector has been moved to Appendix B. A general overview of the different size distributions and of the corresponding experiments is given in Section 2.2. To further improve readability, we now use different notation to indicate the experiments (capital letters, e.g. REF) and the corresponding size distributions (lower-case letters in italic, e.g. *aerocom_land*).
- The section on radiative forcing effects (now Section 7) has been completely restructured. The aerosol RF effects are discussed together with the effects of other compounds (CO_2, methane, ozone) and grouped by sector. Now all three results sections (Section 5 on mass, Section 6 on number and size, Section 7 on RF effects) follow an identical structure.
- The overall length of the paper (excluding the appendix) has been reduced by about one third, with 9 sections.
- Figure 1 (location of the observational stations) has been removed, as this information can be easily retrieved elsewhere (i.e. on the web-pages of the observational network).

We think that this makes the manuscript more streamlined. The reader should be now able to easily access the topic of interest (mass distribution, number distribution, climate impacts) and/or the results for a specific sector.

Other comments.

Many figures could be combined into summary figures.
This is already done with Figures 4 (now 3) and 8 (now 7), which have exactly the purpose of providing a summary of the most relevant species for each sector. From these two figures, the reader can quickly overview the key result in terms of aerosol mass and number. More interested readers could proceed further in the sections and find details about the geographical distribution of the aerosol impacts.

Give one figure per experiment that shows the results of all sectors for all species, like that it will be easier to compare them to each other.
We think that it makes more sense to group the results by simulated quantity (mass, number, size, radiative forcing) and sector (land, shipping, aviation). Comparing experiments to each other, as suggested, would make things quite confusing, given the different scope of the various simulations (or set of simulations) as presented in Table 2.

The radiative forcing numbers should be presented together with the sector experiments
We acknowledge that this suggestion would make the paper shorter. However, this would also

make it more difficult for a reader only interested, for instance, in the RF effects, to find the respective results. As we mentioned above, since the paper is focusing on many different quantities, we believe that the current structure of the paper will help the readers to access the desired information much more efficiently.

The paper fails to puts its findings into perspective.
We do not agree on this point. There are several places throughout the manuscript where a perspective is given:

- Section 6.2 (now 5.2): different relative impact of land transport on BC pollution in different regions (Europe and USA versus Asia) is very important for mitigation strategies.
- Section 6.3 (now 5.3): detrimental health effects due to shipping impacts on the continents (confirming previous studies) and possible changes due to future regulations.
- Section 7.1 (now 6.1): reduction in particle number from aviation with low-sulfur fuels is relevant for future policies.
- Section 7.2 (now 6.2): the large uncertainties in land-transport induced particle number is a strong motivation for the development of more accurate parameterizations of the sub-grid scale particle aging process.
- Section 8 (now 7): the significant role of transport-induced aerosol in altering the climate is now presented in relation to other components, revealing its importance for climate-change-mitigation strategies (this section has been restructured to highlight this issue).
- Section 9 (now 8): the non-linearity analysis reveals that application of linear scaling methods to evaluate mitigation measures should be handled with care.

The above thoughts are further stressed and summarized in the conclusions.

The abstract needs to be more quantitative
The reviewer is right. We extended the abstract including more quantitative information.

P 13122 L 8: 'resulting in change of radiation' please be more quantitative.
We included a more quantitative statement here.

P 13122 L 12: Are the premature death calculated globally?
Yes, we added this to the text. Thanks for pointing this out.

P 13122 L15: Transport emissions cause of main air pollution? Does this consider the effect of biofuel cooking?
Transport emissions include only the effect of transport modes land-transport, shipping and aviation. Biofuel cooking emissions are included in the model together with the other background sources (e.g. Industry, energy production, natural sources, etc.), but are not subject of a target sensitivity analysis as for the transport sectors.

P 13126 L 18: How is the aerosol mixing state taken into account when calculating radiative forcings?
Aerosol are assumed to be in an internal mixture. This is explained in the Model description

section (now moved to Appendix A).

P 13126 L 19: The radiation scheme is decoupled from the model chemistry, what does this mean?
It means that the radiation scheme does not use the concentration of radiatively active gases as calculated by the chemical scheme, but rather uses off-line climatological fields. This applies to ozone, methane, CO_2, N_2O and CFCs. The decoupling is applied in order to isolate the aerosol effect from the effects induced by changes in other compounds.

P 13126 L10: Does the new emission inventory perform better or worse than the old one? What is the difference between the inventories? (There is a section on emissions later, so maybe just remove the emission part in 2.2)
We are not sure what the reviewer means by "emission part in 2.2". In this section (now Appendix A2) we just perform an additional model evaluation, with respect to the previous evaluations of Lauer et al. (2005, 2007) and Aquila et al. (2011), motivated by the fact that a different emission inventory is used in our study. Our goal is not to judge the performance of the inventories used in the different studies, but rather to ensure that the model is providing reasonable results when compared to measurements in the regions of interest.

Fig3/4: Fig 4 shows the importance of Nitrate, why not include nitrate in Fig3?
This is a very good suggestion. We extended this figure (now Figure 3) with two panels for nitrate. A corresponding paragraph has been added to the text in Section 4.

Section 5: Why only show SO4 and BC, why not show all aerosol distributions? As differences are shown later it would be nice to see the reference concentrations. There is not much explanation needed, section 5 could be skipped, simply show the distributions when you discuss the impacts.
With the addition of nitrate, all the transport-relevant species are now plotted and discussed in terms of background concentration.

Fig4. Why is the effect of emissions per sector on mass is only calculated for certain levels? That's not a quantitative comparison.
The goal of Figure 4, as explained in the text, is not to perform a quantitative analysis (which is performed in the later sections), but to give an overview of the most relevant species for each sector. Considering the whole tropospheric domain, instead of specific levels, would not change the key message of this plot, and could give the wrong impression that the impact of some species is negligible.

The size distribution assignment for transportation is simply split over different size distributions. Would it make sense to make the emission size distribution source dependent?
The emission size distribution is source dependent, since different parameters are considered for the different sectors (in the NUC_AIR experiment even for different species), as shown in Table 4 (now 2) and Table B1.

Table 5: Can this table be presented as figure?
This is a very good idea. We replaced Table 5 with Figure 12 showing combined (shortwave+longwave) RF values for all-sky and clear-sky, which are the ones actually important for the discussion. We moved the table to the Appendix (Table C1), since some readers might want to know the exact numerical values without having to guess them from the

plot.

P 13153 L1: Why are aerosols above clouds are not considered in this study? This should be included automatically when running a climate model?
Aerosol above clouds are considered in this study, but their effect is not included in the clear-sky fluxes discussed in this sentence. The all-sky values represent the total radiative effects of transport-induced aerosol, taking also into account changes in the cloud-radiation interactions. In the clear-sky calculations, on the other hand, cloud-radiation interactions are neglected, in order to estimate the importance of non-cloud effects, in particular direct radiative effects of aerosol and water vapour changes.

P 13155 L10: Section 8.3 is the most important part for understanding the relevance of this study. Would it be possible to summarize these results visually? It is difficult to just read through all the forcing numbers. Eventually the net result, including GHG, of emission sources and uncertainties is what we need to understand.
We agree with the reviewer's suggestion. We added the RF of other compounds (CO_2, ozone, methane and contrails for aviation) to the new Figure 12 replacing Table 5. This also allowed us to merge section 8.2 and 8.3 in a single consistent discussion (now Section 7), with the three sectors discussed in separate subsections (7.2-7.4), similarly to what is done in the previous sections. This should improve the readability and help the reader to understand the aerosol RF results in a wider perspective. A minor typo for land-transport RF values of O3 and CH4 was fixed in the text.

P13157 Section 9, effects of non-linearities should be cut from the paper. The paper is already too long and this section ads very little information to this study.
This is one of the novelty aspects of the paper and we believe that it is of relevance for studies focusing on the evaluation of mitigation strategies for air pollution, as pointed out in the conclusions. The length of this section is less than a page and its removal would not significantly reduce the length of the paper. Facing that the main text was already substantially reduced, we think that this result can be kept as part of the manuscript.

Discussion: Similar to the abstract (and keep in mind many people will only read the abstract and the discussion) the discussion should be more quantitative. As an example 'Land transport and shipping are most relevant on continents and oceans..' this result doesn't carry a quantitative message. And that applies to discussion points 1 – 6.
Probably the reviewer means the Conclusions section. The first point is not meant to provide quantitative information, which is provided in the other points for each sector, but to discuss the geographical distribution of the impacts, highlighting the different domains on which the three sectors act (continents/ocean, surface/upper troposphere). The other conclusion points (2-6) already contain quantitative information about the relevant findings of this study.

Similar to the paper the discussion highlights individual results instead of connecting this study to its climate relevance. The discussion should explain the relevance of the transportation sectors, including all co-emitted species and in relation to other anthropogenic sources.
We understand the reviewer's point of view, but we believe that the focus of the paper should not be only on the climate relevance of transport-induced aerosol, but also on their air quality impacts, for which aerosol concentrations and distributions are the critical quantities. The relationship between the transport sectors is discussed in point 1. The importance of land

transport with respect to other anthropogenic sectors is highlighted in point 2. Shipping and aviation act on exclusive domains, where they are the only anthropogenic source of pollution, therefore there is no point in relating their effects to other sources.

The paper lacks any discussion on uncertainties introduced by the host model and microphysical schemes.
We agree with the reviewer that such an analysis would be very valuable. However, quantifying the uncertainties introduced by the host model and by the different parameterization would require an intercomparison between different models focusing on process-oriented evaluation, which is beyond the scope of the current study. The model system adopted in this study has been extensively evaluated in previous papers (Lauer et al. 2007 and Aquila et al. 2011, who also compared EMAC-MADE results with the AeroCom multi-model average). An additional model evaluation, focusing on highly polluted regions, is presented in the manuscript (now in Appendix A2).