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Interactive Comment

Interactive comment on "The global impact of the transport sectors on atmospheric aerosol in 2030 – Part 2: Aviation" *by* M. Righi et al.

M. Righi et al.

Mattia.Righi@dlr.de

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We are grateful to the reviewer for his/her constructive comments and suggestions which helped us to improve the manuscript. Please find below our replies (roman text) to the reviewer's comments (*italic* text).

Section 1-Model setup, emission inventories and model simulations. This part is crucial to understand which set up of the model and emission inventories have been used. To my view, it needs to be extended and restructured (may be by adding a section dedicated to emission).

Since Reviewer 1 has raised similar concerns, we have extended the emission description by including more precise statements on: i) which species are actually included in the CMIP5 inventories; ii) which species are not included and how they have been derived; iii) how number emissions were calculated from the mass assuming specific size distributions. We have also extended Fig. 2 to provide number emission totals in the different regions in addition to mass. However, since the model and emissions setup has been extensively described in the companion papers (Righi et al., 2013, 2015), we would like to keep this section short and avoid unnecessary repetitions.

First, as the indirect effect of aerosol is activated, it is important to describe how it is implemented into EMAC.

This is a good point, thank you for raising it. The following sentence has been added in Sect. 2 to describe how aerosol-radiation and aerosol-cloud interactions are simulated in the model: "The model setup adopted in this study also includes aerosol-radiation and aerosol-cloud couplings (Lauer et al., 2007), which are essential for quantifying the aerosol impacts on climate. The first is realized by explicitly calculating aerosol optical properties on-line based on the Mie theory and using them to drive the radiation calculations (see also Pozzer et al., 2012). The latter follows the Abdul-Razzak and Ghan (2000) parameterization to simulate the number of activated cloud droplets as an input to the two-moment cloud scheme by Lohmann et al. (1999) and Lohmann (2002). This enables to track cloud particle number concentration and its aerosol-induced changes. It is important to mention that the current model setup does not include the representation of heterogeneous freezing process in ice clouds (this is intended to be the subject of a follow-up study)."

Secondly, the description of the aviation emissions from the RCPs is only done partially. It would be nice to have a more specific description of the data used for the

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aviation emission (e.g. assumption made for traffic growth, fuel efficiency) especially the ones coming from the RCP2.6. For example, the huge increase (2000-2030) for BC in RCP2.6 would need more explanations.

The RCPs are general-purpose scenarios covering all sectors and they were not specifically designed for aviation. Therefore, they do not follow the standard methods used in other transport scenarios (e.g., QUANTIFY). As we state in Sect. 2, they are mostly based on (or rescaled from) existing scenarios, often following very basic assumptions. Despite their limitations concerning the short-lived species (see, e.g., Takemura 2012), our main motivation for using the RCPs was that they were specifically designed for the IPCC and a large number of single- and multi-model studies are based on them.

Lines 16-23 p34042 need clarification, maybe by adding a table, summing up the actual data used.

Detailed information about the RCP emissions, including spatial distributions and totals for all sectors and species, is freely available on-line (e.g., http://tntcat.iiasa.ac.at/RcpDb/dsd?Action=htmlpage&page=compare) and in the cited literature. Since the focus on our study is on the quantification of the impacts and not on the development or evaluation of emission inventories, we would like to show and discuss only those aspects which are relevant for our conclusions. We believe that Fig. 2 (now extended) and the discussion in Sect. 2 (also improved) provide the reader with the required information for interpreting our results. The readers who are interested in the emissions generation process may refer to the cited literature or to the companion paper (Righi et al., 2013), where a more extensive discussion on emissions was provided.

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Section 3- Aviation impact on aerosol in 2030. The figures associated to this part are nicely chosen but weakly commented. Rather than writing "the contribution of the aviation sector to the mass concentration changes remains small, as it is clear from the comparison of the left (all sources) and the right (non-aviation sources) columns", a full description and discussion of the aviation impact for sulfate and nitrate should be done including quoting the numbers.

We have improved the discussion in Sect. 4 with more quantitative statements and a better discussion of all the relevant figures.

Section 4- Aviation impacts on Earth's radiation budget. As well as decomposing the radiative forcing effect by RCP, I would suggest to do it for the direct and the indirect effect for each species and discuss it. Also, the role of sulphate into the cloud microphysics is described but the influence of the strong increase of BC is not discuss but should be.

Separating the effect of each species on the radiation budget would require additional experiments. The increase of BC is not relevant in this study since our current model setup does not include the hetereogeneous freezing process and the resulting impact on cirrus. We have added this to the model description: "It is important to mention that the current model setup does not include the representation of heterogeneous freezing process in ice clouds (this is intended to be the subject of a follow-up study)"

Page 34047, L 10-14: I would suggest also to look at the data from Pitari., et al, 2015 to enhance the discussion about the direct and indirect radiative forcing.

We thank the reviewer for pointing us to this interesting study. Although it is based

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on year 2006 and hence is not fully comparable to our results, we have included this reference in the discussion at the end of Sect. 4, as follows: "Pitari et al. (2015) estimated the direct aerosol effect from aviation using the REACT4C inventory for 2006 (Søvde et al., 2014). They found a RF of –3.4 mW m^{-2} (for sulfate) and 0.86 mW m^{-2} (for BC). This results in a total direct RF for aviation of –2.54 mW m^{-2} which compares very well with our clear-sky RF for the year 2000 of –3.2 mW m^{-2}, although clear-sky forcing is only a proxy for the aerosol direct effect and our estimates also includes the effect of aerosol nitrate. Their estimate for the indirect effect cannot be compared with ours as they only considered the effect of BC on cirrus clouds, which is not covered here. "

Page 34048, L 10-12: I would temperate the statement "without the implementation of significant technological improvements to reduce the emissions" as ACARE has clear goals related to air pollution emissions including a reduction of CO2 (-75% per passenger kilometre) and NOx emissions (-90% per passenger kilometre) by 2050 relative to 2000.

We agree with the reviewer's suggestion and replace this sentence by a more moderate statement as follows: "This is essentially due to the strong growth of air traffic volumes which counteracts the effects of implementing significant technological improvements to reduce the emissions, ..."

Page 34049, L 8-11: I am not sure where this statement has been shown in the paper.

In Sect. 4 we show that that extremely large values for the aviation RF are estimated if a size distribution is assumed, characterized by a large number of primary sulfate particles emitted in the size range of the nucleation mode. This is based on a rescaling of the RF following the uncertainty range found in R13 for the 2000 case. We have added a reference in the text to clarify this.

Abstract: Define acronyms ECHAM, MESSy and RF.

Done. Definitions for ECHAM and MESSy have been added in Sect. 2 (to keep the abstract readable)

Page 34042: Define all variables of the four equations.

Missing definitions have been added. Thank you for spotting them.

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