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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Climate benefits of proposed carbon dioxide mitigation strategies for international shipping and aviation" *by* Catherine C. Ivanovich et al.

Anonymous Referee #1

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This paper investigates the potential for reducing the climate impact of international aviation and shipping over the 21st century. The policies and targets adopted by the IMO and ICAO are translated into emissions scenarios and the subsequent impact on global mean temperature response assessed using the reduced complexity climate model. Knowledge of how these sectors can reduce the climate footprint and align with the goals of the Paris Agreement is important and the study hence provide a topical contribution. The paper is well-written and clearly structured. I do, however, have some concern about the methodological assumptions, and would like to see a better treatment of uncertainties as well as better integration with the current body of literature and status of knowledge before the paper can be published in ACP.

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Discussion paper

General comments: I believe that excluding the contrail-cirrus effect is a major limitation of this study, which, although the authors repeat the caveat, gives misleading results. I find it particularly problematic since the authors choose to include indirect effects due to aerosols, which are much less studied and have even larger uncertainties. Moreover, the authors refer to a paper by Skeie et al. 2009, and in this study an estimate of the contrail impact was included. At the very least, the authors need to better justify this choice and better reflect the large body of literature on contrail-cirrus to give a qualitative estimate of how their results could look if this was included. Some modification of how the temperature impacts of all pollutants are presented should be made.

Another major limitation is the lack of uncertainty assessment. I strongly encourage the authors to include some sort of uncertainty calculation here, given the large uncertainties in RF estimates and climate sensitivity.

Related to this, I also feel that the discussion is incomplete and that there are several issues where further elaboration and caveats are needed, and where existing literature should be better reflected. Moreover, additional results such as emission pathways and RF estimates should be provided in order for the reader to better be able to understand the drivers of the temperature response, potential impact of uncertainties and differences compared to previous results. See specific comments below.

Specific comments:

Pg1, line 27: “emissions from these” – should this be “emission reductions from these”?

Pg1, line 34-35: What is meant by “over a 20- and 100-year timeframe”? Is this because you’re talking about CO2-equivalent emissions? Please correct/clarify.

Pg3, line 31-35: does this mean that there are in fact four BAU scenarios for aviation, the three sensitivity ones and the one described above on lines 27-30? Please clarify.

Pg3, line 31-35: it would be very helpful for the reader if the future emission pathways

under the scenarios and alternative BAU were shown.

Pg4, line 4: what's the rationale for selecting this one?

Pg4, line 29-30: I think this sentence fails to take into account the large amount of previous and ongoing work on contrail-cirrus across many groups. While certainly true that there is an significant uncertainty bar on the contrail-cirrus RF estimate, significant progress has been made over recent years and I encourage the authors to reflect this.

Pg. 4, line 26: What about the even more uncertain indirect effect of shipping sulfate aerosols? Is that included and how?

Pg4, line 32: this is not necessarily the case if the offsetting schemes include a switch to biofuels – see e.g., Caiazzo et al. 2017 ERL, Burkhardt et al. 2018 npj Climate and atmospheric science.

Pg6, line 9: what is the climate sensitivity of MAGICC?

Pg6, line 24: please be more specific. Are particular parameterizations for the aviation and shipping sectors used? Also, given the large uncertainties in the RF of many climate-relevant components, which in turn are critical for the total temperature impact (see also comment below) and hence the contribution of aviation and shipping, the authors need to provide information about the RF estimates (present day relative to pre-industrial) underlying their simulations. In particular, RF estimates specific to aviation and shipping – e.g., what is the indirect aerosol effect of shipping and aviation? And NOx-induced O3 and CH4 effect of aviation? This will allow the reader to better compare to previous literature and assess differences between studies. The current study should be compared with previous results. While, as the authors state early on, there are limited number of studies of temperature impact of different sectors, there is a large body of literature on RF.

Pg7, line 14 – onwards: in this study, I believe all aviation scenarios are compared with the same baseline for global emissions (RCP8.5)? I think a nice addition would be to

discuss the sectors contributions given that not only they, but also the rest of the world makes progress on emissions.

Pg7, line 30: again, this is an example of where information about underlying RF is critical and should be compared with previous literature.

Pg8, line 2: compare with other studies? E.g., Fuglestvedt et al. 2009.

Pg8, line 19-21: for both sectors, the authors should also note that the calculations assume no change in geographical distribution of emissions. For non-CO2 emissions, location can be critical for the subsequent impact. E.g., Fuglestvedt et al. 2014; ES&T, Köhler et al. 2013 Atm. Environ; Frömming et al. 2012 JGR; Lund et al. 2017 ESD

Pg8, line22 – onwards: As already pointed out in the major comment, I believe this result in misleading given the lack of treatment of contrail-cirrus. While it possible that the indirect aerosol effects of aviation sulfate and BC could be negative enough to cause a net cooling, there is nothing in our current best understanding that suggests so. If included I think the authors should make a point of the missing effects at the very start of this paragraph not at the bottom, emphasizing that one should be careful not to read too much into this finding.

Pg8. line 31: again, the estimates of indirect aerosol RF should be included for comparison with e.g., Gettleman et al. 2013 GRL.

Pg9, lines 7-10: Skeie et al. 2009 included both indirect aerosol effects and contrail-cirrus forcing – see their figure 2. Please correct or specify which indirect effects beyond there is included in this analysis.

Pg9, line 9: is the net NOx RF negative in Skeie et al. for shipping?

Pg11, line 4: the IPCC report on 1.5 degrees showed that there was a large difference between temperature response and time until reaching temperature thresholds between two simplified climate models. Uncertainties in the background temperature response affects the contribution from aviation and shipping, and should be discussed

somewhere in the paper (perhaps the authors should consider a dedicated discussion section).

Figure 4: the authors should show also the CO2 only cases here, as in Figure 2, allowing the reader to assess the impact of the assumption that non-CO2 emissions are changed “proportionally”.

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