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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Modeling the present and future impact of aviation on climate: an AOGCM approach with online coupled chemistry" *by* P. Huszar et al.

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Response to Referee 1 comments

Referee's comments are highlighted in *italics*.

- *Overall comment*

  Although I agree that responding to all comments of the first reviewer would make the paper much stronger I keep my recommendation reached earlier, i.e. "pub-

lishable after major revisions". The step of addressing the issue of aviation impact with a coupled chemistry-climate model is an important one, even though (given the strong simplifications) it is small. Addressing the following weaknesses appropriately would give better confidence that it is a small step into the "right" direction:

The chemistry is very simplified and is integrated only in a specific height range. Is this to save CPU time? This has to be explained in more detail. The distributions of chemical species in this model configuration should be compared systematically to observational data before the scheme can be used.

Thank you for reviewing our manuscript and for all your recommendations to improve our paper. We have addressed all your comments and below are our responses to each of them. We will sometimes refer to responses to the 2^{nd} referee. The most important changes in the revised manuscript with respect to the ACPD version are listed at the end of our responses.

A much detailed description of the chemistry scheme is included in the revised manuscript. It is true that the chemistry included so far in our General Circulation Model (GCM) does not include the detailed non-methane hydrocarbon (NMHC) chemistry specific of the lower troposphere. However, for the rest of the atmosphere, including the upper free troposphere from 560 hPa up to the lower mesosphere (about 70 km), the chemical reactions of our scheme correspond to that of state-of-the-art chemistry-climate models (see Morgenstern et al. (2010); SPARC (2010)). This scheme calculates the evolution of 55 species using 160 gas-phase reactions, with the JPL chemical kinetics of Sander et al. (2006).

The chemistry is computed down to the 560 hPa level while for higher pressures the mixing ratios of a number of species (namely N2O, CH4, CO, CO2, CFC11, CFC12, CFC113, CCl4, CH3CCl3, CH3Cl, HCFC22, CH3Br, H1211, H1301, Ox, O3, Cly, Bry, NOy) are relaxed towards evolving global mean surface abundances (see SPARC (2010) for the ozone depleting substances and greenhouse gases,

and the CNRM-CCM technical documentation for the other compounds). Explicit wash-out of chemical species is not considered in this version of the model, and neither are convective and turbulent transport. In addition, three types of particles are considered in the heterogeneous reactions, liquid stratospheric aerosols and Polar Stratospheric Clouds (PSCs) that include water ice and NAT (Nitric Acid Trihydrate) (see Teyssèdre et al. (2007); Michou et al. (2011); Morgenstern et al. (2010) for further details).

Including the NMHC chemistry, and the wet-deposition and convection of chemical species would increase the computational costs greatly, making it more difficult to perform transient experiments like ours which consider the whole climate system, including the deep ocean, the sea-ice and the atmosphere up to the lower mesosphere.

There is very little significance to the results. I assume the reason why 90% level was chosen is because at 95% one would have given almost no significant results. If so, more ensemble members or emission scaling should be used.

We reevaluted the significance of the results which are now presented at the 95% significance level, much more acceptable by the scientific community. This of course decreased the significance of certain results, but the overall picture about the aviation impact on temperature remains unchanged.

The choice of not scaling the emissions is explained in the response to the 2nd referee, see point 2. (second comment.). The revised manuscript nopw contain explanation why we have not chosen this approach. Running the experiements in ensemble mode was than necessary to obtain higher signal to noise ratio. The results showed that 3 members are too few to get clear signal at the surface but appear to be enough for higher altitudes from the mid-troposphere up to the mesosphere.

- *Specific comments*

Responses to the most important specific comments follow:

3833 line 17: why does the CO2 enhancement due to aviation lead to a decrease in surface temperature? It says later on that this might be due to "some complex feedback mechanism", but can anything more specific be said? It's a bit surprising and it's not only the Arctic.

We identified that a positive sea-ice bias in our experiments influenced greatly the surface temperature impact of the aviation emissions. We further found that the sea-ice amount in the individual simulations did not follow scientific expectations, given the sign of the radiative forcing of the aviation emissions. Therefore, the impact of the various emissions from aviation on the surface temperature can be fully masked on some of our simulations. This is discussed more precisely in the revised manuscript.

3836 line 18: it would be better to show changes in chemical constituents before their impacts, i.e. move section 3.4 before the sections where their climate impacts are discussed.

We rearranged the section and we now present the chemical perturbations before showing the climate impact of these perturbations.

3837 line 8: why does NOx go down in the near future due to aircraft NOx emissions?

In the revised manuscript, we now present the JJA (June-July-August) NOx and ozone perturbations that have been evaluated in most previous CTM studies, enabling a direct comparison. Secondly, we present the chemical perturbation with the same significance level (95%) as the temperature impact. Given this, the NOx perturbations in the three selected periods are now coherent with increasing emissions, and the stratospheric perturbations are usually not significant.

Table 1: what is the difference between "DEFchem" and "noAVIATION"?

The DEFchem simulation differs from the noAVIATIOn simulation in the prescribed tropospheric relaxation values of a number of chemical species. In the first case, the relaxation values account for the aviation emissions while in the noAVIATION experiment we adjusted these relaxation values to reflect zero emissions from aviation. See Section 2.4 for more details.

Please find below a list of the most important changes made in the revised manuscript:

- we rearranged the list of authors to reflect the additional work done on this paper during the review procedure.
- the Introduction is more precise in defining the goals of the study.
- the model description is more detailed, with a focus on the chemistry scheme. The contrail parameterization is also more lengthly described, and the contrail and induced cirrus RF is compared to previous studies.
- the section on the evolution of the mean climate is now analyzed in more detail, and presents, besides the temperature, the Arctic sea-ice extent which influences greatly the surface temperature.
- the section on the CO_2, NO_x and ozone perturbations has been shifted before the ones on the impact of aviation upon climate. It is compared (there or in the discussion) to previous studies and discussed in more detail.
- in the sections on the impacts upon temperature (globally, zonally, monthly), the significance has been recalculated and colors indicate now the 95% level of significance. Analyses have been modified accordingly.

- the discussion has been extended with more comparisons and analyses. Figures have been added among which one shows the mean impact on the Arctic sea-ice extent of different aviation emissions, which we found related very closely to features of the impact on the global mean temperature. The aviation NO_x induced chemical perturbation is also presented and analyzed in terms of its variability.

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