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Interactive Comment

Interactive comment on "A strategy for climate evaluation of aircraft technology: an efficient climate impact assessment tool – AirClim" *by* V. Grewe and A. Stenke

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Answer to Referee 1

Referee 1 had in principle four comments:

1. presentation not clear enough
2. results should be discussed with respect to other metrics
3. Title too long
4. CO_2 modelling should include more sophisticated approaches

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Interactive Discussion

Discussion Paper

1) Agreed. We are thankful for the specific comments, which hopefully help to clarify the presentation. We tried to better structure the sections.

2) Concerning the discussion with respect to other metrics, this is now added to the discussion section (incl. the references).

3) Agreed - changed as recommended.

4) Agreed; a more complex model is implemented (SausenSchumann, 2000)

Additional changes:

- A bug in the methane RF calculation removed.
- RF intercomparison is now discussed in more detail and moved to the section on verification of the model. Principle differences in the calculation of methane is discussed. An appendix is included desribing in more detail the methane calculation.
- Uncertainty analysis is included. Especially for Figures 10 and 12 (submitted version) (11,13 revised). And a subsection on the assumed uncertainty ranges is added at the end of Section 2.
- Table 6 revised. Some of the data were simply wrong (Contrails, H2O), for others the method is updated see above (CO_2, CH_4).
- abstract shortened. Focus on methodology.

Specific remarks:

p 12186

17-19 The lifetime of the perturbation depends on the region, where the emission occurs. This is taken into account and clarified in the abstract.

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22 Sorry. Latest changes to clarify the sentence definitely failed. Here a correction:

Between 2000 and 2050, CO_2 and NO_x subsonic air traffic emissions lead to approximately the same impact and increase rates as long as the fuel consumption increases by approximately 6 to 7% per year. Assuming a constant emission rate afterwards still leads to similar impacts on temperature in 2100, although ozone-radiative forcing is much less important due to its shorter lifetime.

28 nm=nautical miles, which is used by aircraft manufactures. km are included for clarity.

CO_2 versus NO_x: Based on Sausen et al., 2005 the most important to RF are CO_2 and Ozone. Contrail-cirrus may change the picture -however not included in our considerations, since the knowledge is still too limited. This is now mentioned in the conclusions.

p 12187

5-8 agreed and included.

10 thanks

21 changed

p 12190 13-17 Scenario A1B

p 12991 the reference is misleading and taken out.

p 12192

2 Efficacies vary in most cases in the range of $\pm$ 10-20%. Deviations are larger and only for some cases (stratospheric ozone). This has of course an impact on absolute values of dT especially in the case when stratospheric ozone is important.

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However, direct intercomparisons of aircraft technology is less affected, since, even with a variation within a parameter range, the parameters are equal for both cases. see eg. Fig. 11 (submitted version) 12 (revised version). For aircraft related pattern efficacies were uniquely calculated by Ponater et al. A discussion of the uncertainties in the efficacies is added.

20 As stated in the text, this applies for supersonics, only. Fig 11 (12 revised) + discussion shows ozone depletion, which is taken as an indicator for UV changes, added to the text in respectie section.

p 12193 ok

p 12194

7-8 Adapted according to Sausen and Schumann, 2000. Text and Figures updated. Only minor changes, since the lifetime was chosen to represent a mean response of Sausen and Schumann and IPCC99. Changes occur mainly on larger time-scales (2250).

10 The description of the procedure seems to be not clear enough. We have added a paragraph, which describes the general procedure. For the time (T_{const}+tau), which is representative for the steady-state simulation, a concentration change is calculated by folding the emissions with the results from the idealised scenarios. The temporal evolution of the concentration changes is calculated with a linear differential equation, where the lifetime change is calculated analogously to the calculation of the concentration changes. dx/dt=sP-(1/tau) x. The production term P is given by the CO_2 emissions (E_{CO_2}) scaled to fit the concentration change at $T_{const} + \tau$.

p 12195 12-14 The background scenario is A1B. The change in methane lifetime is time dependent. At the time of in-service the change is 0 and increases to delta at time

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T_{const}. An explanation is added, see also appendix.

p 12196 15 In principle several response times could be used to represent the temperture repsonse. However earlier findings suggests that one lifetime is sufficient for the current application. The lifetime of 36 yrs includes the response of the deep ocean since the model used for the linerisation is an atmosphere model coupled to a 11 layer deep ocean (5000 m), whereas Shine et al., 2005 (Climatic Change) considered a 100m mixed ocean, which has considerably faster response times. An investigation of all sensitivities would be interesting but cannot be performed in this framework, we leave it open to future studies to include different metrics and ways to calculate GTP. A short reference to Shine is given to avoid misunderstandings in the response time.

p 12197 Since the approach has been updated, the comment is now irreleveant for the paper. The difference was in the order of 10%

p 12199 5-13 I am not aware of publications discussing the horizontal gradient of the atmospheric sensitivity (in terms of ozone-RF) with respect to NOx emissions. This includes a) chemistry and b) RF calculations. There are however, investigations discussing the impact on RF for a given ozone field e.g. Joshi et al., 2003. The results (their table 2) show that the models agree within an 25-30

Currently feed-backs on ozone from methane changes are not fully taken into account. The ozone change steady state simulations include some of the feedbacks, since methane responses to the changes in ozone and vice versa. This is mentioned in the conclusion.

p 12200 We revised Fig. 1 to make it clearer. Actual RF values are calculated by folding emission data with the RF values from the idealised scenarios. A reference is given to Fig 1.

p 12201 comments on CH_4 and O_3 Concerning the verification of the model with respect to O_3: first the pattern are similar. Stratospheric ozone losses and tropospheric

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ozone increases are well reproduced. RF-O3 is the sum of warming from emissions at lower altitudes and cooling resulting from emissions at higher altitudes. Hence it is a residuum, which is difficult to assess. For methane, we have updated our RF calculation and fixed abug (thanks!) for methane changes, taking into account the approach from IPCC(2001) page 358, as has been done e.g. by Sausen et al., 2005. Concerning the intercomparison with subsonic aircraft simulations the intercomparison has been extended to E39/C data, which are directly intercomparable. Additionally, it has to be taken into account that Sausen et al., (2005) calculate a methane lifetime change for the year 2000, which is a result of a steaty state simulation and would - in reality - actually be achieved at a later time than 2000. This temporal shift has been taken into account in AirClim. Hence it is more appropriate to compare RF values at 2010 (in the case of 12 yrs methane lifetime) with the 2000 values given in literature. To illustrate this we also present a calculation identical to that of Sausen et al., 2000 but with the methane lifetime change calculated with AirClim.

p 12202 Historical data for fuel use are taken from IPCC (1999), i.e. avaialbale for 1940, 1960, 1976, 1980, 1992. The data inbetween are interpolated, assuming a constant percetage increase between two times, which leads to an exponential increase.

24-26 see above p12201

26 Text is re-written and more focused on a direct intercomparison of E39C results. The results are also in the range of modelling results in IPCC (1999) and Sausen et al. (2005). Table 6 extended by E39C results, so that data are directly intercomparable.

p 12203 yes. The resolution is not high enough to correctly represent water vapour effects (vertical gradient in water vapour) for subsonic air traffic. Values are simply adjusted. The conclusion clearly states that a higher resolution is needed for this application. re-written

13-14 done

18-19 It shouldn't be misinterpreted as a forecast. Hence it only shows how fast the steady stade is reached and at what level.

24 included specifically in the text (r=1 for CO_2, r=1.18 for CH_4, r=1.4 for ozone, r=0.59 for contrails r=1.14 for H_2O)

Fig. 10. One argument often discussed is that CO_2 emissions become more important than NO_x emissions in the long run (2100) and RF may indicate this, but dT needs longer to show this effect. We extended this discussion to make that point clearer.

p 12207 a range is given.

p 12208 9 agreed

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 12185, 2007.

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