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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Climate impact of supersonic air traffic: an approach to optimize a potential future supersonic fleet – results from the EU-project SCENIC" *by* V. Grewe et al.

V. Grewe et al.

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Reply to Referee 1

The referee was quite positive about the manuscript, however had some concerns, which we would like to comment. We have included most of them in the manuscript, which improves especially the conclusions - thanks to the referee.

1st comment: Atmospheric fraction correct? The integrated emissions from 1990 to 2050 (61 years) for S5 are 8.986 ppmv, well estimated by the referee. The CO_2 concenration in 2050 is 6.14 ppmv as cited by the referee. This would give a fraction of 68%, which is considerably more than the value estimated by the referee

(40%). I am not quite sure where this 40% value is coming from. Unfortunately, the referee didn't give a reference. E.g. IPCC (2001) gives the following values for 1990-1999:

Atmospheric increase	3.2 PgC/year
Emissions	6.3 PgC/year
Increase rate between	80s and 90s : ≈0%

This gives a value of 50%, the respective value for the 80s of 60%.

Indeed, looking at the temporal development of these atmospheric fractions to the 2050 concentration we find values as low as 30% in the 90s and more than 90% in the 2050s. Since the emissions are increasing with a rate of roughly 3% the impact from recent years is much larger leading to larger fractions compared to the background values.

After 2050 the emissions are kept constant and the atmospheric fraction is reduced to 58% in 2070 and 48% in 2100.

In general, the background values are difficult to compare with the perturbation values, since large changes in background values, e.g. due to increased emissions, change the atmosphere-ocean and atmosphere-land fluxes and hence the atmospheric residence time.

Perhaps a thought-experiment helps to understand this situation. Two scenarios are considered which have the same total emissions of CO_2 but in a different temporal evolution:

1. Assume an exponential increase of CO_2 emission perturbations, i.e. a small increase in CO_2 emissions, which exponentially increases with time (but still small compared to the background). Then the total emissions are dominated by the very recent years. Those emissions have large atmospheric fractions.
2. Assume an exponential decreasing CO_2 emission. The total emission is dominated by the early years. The concentrations are hence much smaller

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at the end of the regarded period since the emitted species have more time to be exchanged by land or ocean processes. Hence the atmospheric fraction is much smaller than for 1) although the integrated emissions are the same.

Therefore the temporal development of the perturbation scenario very much determines the atmospheric fraction rather than the background.

We regard this referee's comment as a valuable note and cross check. However, we think that a specific comment hereon is beyond the scope of the manuscript and would distract the reader.

2nd comment: More details on climate-chemistry feedbacks In general these feedbacks have been omitted as a first step. I.e. the calculations were performed without feedbacks from ozone and water vapour perturbations. The ozone and water vapour changes cause changes in the vertical profile of the heating rates. Water vapour changes lead to a decrease in stratospheric heating rates and increase in upper tropospheric heating rates in all models. The net heating rates are dominated by the longwave contribution. Ozone changes lead to a decrease of the net heating rates, peaking at around 200 hPa for SLIMCAT and OsloCTM2 models. In the ULAQ model the ozone increase at lower stratospheric levels leads to an increase of the heating rates, whereas in E39/C the effects are balanced. Naturally this has an impact on the circulation. Within the SCENIC project we performed feed-back calculations e.g. with E39/C. These simulations mainly show a statistical sigificant increase in the stratospheric water vapour concentration of 100 ppbv on both hemispheres, which is roughly 1/3 of the direct increase of water vapour due to the substitution of subsonic aircraft by supersonics. The increase is accompanied by an increase in the cold point temperature and an increase in the water vapour entry level, which were, however, not statistical significant. Therefore, the mechanism how climate change, induced by the substitution of subsonic

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by supersonic aircraft, leads to an increase in stratospheric water vapour remains unclear. We included a whole section "Discussion of uncertainties", since we agree that these feed-backs have the potential to alter these results. However, the main results would be qualitatively unaffected since water vapour is already the most important climate agent with regard to supersonic transport.

3rd comment on seasonal cycle of water vapour loss rates Indeed the models show a seasonal cycle in water vapour with largest values in the perturbation field around August/September. The largest seasonal cycle is found for E39/C with an amplitude of around 20% in the max. values. For computational reasons we concentrated on annual mean values for the calcualtion of the RF. We rate this as a minor uncertainty, since it would mainly affect shortwave radiation, which is a minor contributor to the H_2O-RF.

As for the comment above, we included this discussio in a new section "Discussion of uncertainties".

4th comment on RF from subsonics For 2050 the total aircraft-RF was estimated by IPCC (1999) to be 190 mW/m2 and by Grewe and Stenke (this issue to be submitted) to be 203 mW/m2. Hence 22 mW/m2 is in the order of 10% with respect to RF. With respect to the temperature change for 2100 the replacement leads to 21 mK, whereas the background subsonic air traffic amounts to 190 mK. This has been added to the Discussion Section.

Specific comments Done. Specific changes and explanations for some comments are given below.

P.6150, l25 A fixed boundary is chosen to reach steady state in a reasonable time. Since the lifetime of methane is roughly 9 years this would require simulation lengths of 15 years.

P.6156, l5-8 The ozone increase found in some models at lower altitudes is a superposition of various processes. The turn-over point from ozone production

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(troposphere) to ozone loss (mid stratosphere) for an additional NO_x emission is simulated differently by the models. Additionally, the vertical transport of nitrogen oxide enhanced airmasses and ozone depleted airmasses from the mid stratosphere to the lower stratosphere and tropopshere is also simulated differently. The E39/C and ULAQ models, which have the lowest ozone depletion also least compensate the NO_x induced ozone production in the lower stratosphere by downward transport of ozone depleted airmasses.

P.6158, l10 Indeed the 1.6% change of contrail coverage is significant, however it can be regarded to be negligible.

P.6160, l12-14 adapted.

P.6161, l9 The dynamical processes are highly non-linear. However transport of species is not (except for very few processes, e.g. those mentioned in the text). Assume two specie X and Y with Px and Py production terms (e.g. emissions) and D loss term (equal for both). D and P may be time dependent and D linearly depend on X (i.e. dX/dt=Px-D*X). Take now additionally into account transport of the specie. Then for most cases (e.g. ozone) for a specie Z (dZ/dt=Pz-D*Z) with Pz=Px+Py holds Z=X+Y. And with Pz=a*Px it holds Z=a*X. In this sense transport is a linear operator. However, we prescind from including this explanation in the text and point out that dynamics are non-linear.

P.6131 re-phrased.

Comment to conclusions We have to correct one statement in the conclusions, which was wrong. The intercomparison between super and subsonic aircraft, which was based on the intercomparison of TRADEOFF and SCENIC results is incorrect for a couple of reasons:

- Considered time horizon is different, which leads to different CO_2 accumulation effects.
- The considered aircraft fleets are too different to be intercomparable.

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We replace it by a passage, which refers to an upcoming paper (to be submitted in August 2007), in which SCENIC supersonic aircraft are directly intercompared with respective subsonic aircraft.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 6143, 2007.