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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Modelling the impacts of climate change on tropospheric ozone over three centuries" *by* G. B. Hedegaard et al.

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Answers to anonymous Referee #1

We thank referee #1 for a thorough review of our paper. In the following we answer the issues raised by the reviewer:

General:

Reviewer: The authors present the results of simulations done with a hemispheric chemistry transport model using fixed anthropogenic emissions. The simulations are forced with ECHAM5/MPI-OM meteorology and cover four 10-year time slices representing the 1890s, 1990s, 2090s, and the 2190s. The meteorological data are based on the greenhouse gas emission scenario A1B.

Several similar modelling studies have been published in the last years, either using regional, hemispheric or global models. Even the authors themselves have previously published a similar investigation, differing from the current study only by another choice of meteorological data (ECHAM4 with A2) and a different selection the of time slices. Although no simulation results have been published so far for exactly this particular combination of GHG emission scenario and time slices, many of the principal results shown here can also be found in previous studies. To justify a publication, it would be necessary to concentrate on the few new outcomes, which has not yet been done consequently. Therefore, I recommend revising the manuscript in order to highlight and analyze those results that have so far not discussed in previous publications.

Answer: It is true that several studies have been published in the last year on the issue of climate change impacts on future air pollution levels. In our paper we give a thorough overview of the previous studies within the field of climate change and air pollution interactions. However, we do not agree that the results presented in this paper have been published before. The study here is a continuation of a previous investigation, where the importance of ozone was established, but differs on several points: First of all, it is new to make an investigation over three centuries, where the main focus have been to study whether the significant changes in the ozone levels in the 21st century are unique or whether they are also seen in the 20th century or in the 22nd century. Knowing that the ozone levels are changing significantly in the present century, our second goal has been to estimate the magnitude of the changes in the previous and coming centuries relative to the present. This is important for understanding the strength of the climate change and air pollution interaction in the 21st century where the major changes are simulated. Thirdly, we have made a more thoroughly investigation of the chemical processes in order to understand the ozone tendencies, including an investigation for the free troposphere. Finally, we find in the paper that major and significant changes occur in the Arctic area, and we include a discussion and possible explanations on this issue.

ACPD

11, C3604–C3610, 2011

To clarify what is new in the paper compared to the previous studies, we have inserted the following text in the end of the “state of the art” section:

“The first aim of this study is to analyse the climate change impacts on the ozone concentrations over three centuries. In previous studies, the focus has solely been on the 21st century, where a significant change is found. It is therefore interesting and important to find whether this significant change is happening only in this century or whether it also is present in the previous or coming century and to compare the magnitudes of the changes over the centuries. The second aim of this work is to investigate in more detail the chemical and physical mechanisms behind the changes in the ozone concentrations. Simulations over three centuries provide the basis for a more deep understanding of the background for the changes in the ozone concentrations in the Northern Hemisphere in 21st century. Furthermore, the present study is carried out with an updated version of the whole model system and a newer scenario compared to the study in Hedegaard et al. (2008).”

Reviewer: With respect to the presentations of the results it self, the paper leaves the impression that the authors put generally only little effort into this. Thus, it is absolutely necessary to improve them. Particularly the quality of the figures is very poor and uninspired. There are too many stamp-size figures where almost nothing can be recognized. It should be possible to distinguish the relevant features on a printout of the paper and not only when the figures are enlarged to 200 or 300 %! Therefore, the general concept of the figures should be revised. I can imagine that the quality could be increased by testing different colour schemes (maybe rainbow would show more features for mean fields), a smaller number of colour shades, and avoiding the empty space on the right to get larger pictures. The authors should also present some results in a different kind of figure (e.g. line plots, bars showing differences for single grid points or regions, etc.).

Answer: We agree with the reviewer that the quality of the figures could be improved. New and clearer versions of the figures will be included in the revised version of the

ACPD

11, C3604–C3610, 2011

paper. However, as the paper is already quite long, we do not plan to include more figures in the paper.

Reviewer: The paper should only be accepted after a substantial revision. This revision should also include some changes in the general setup of the paper. One option might be the reduction or even omission of discussion parts that only confirm the results of previous studies –in favour of extensions with respect of points which are not or only briefly addressed so far. Another option might be putting this study into a larger context by a more thorough reflection of previous work (e.g. by discussion differences between the 1990s/2090s results of the current and the author's previous simulations.).

Answer: We do not agree with the reviewer that the paper needs substantial revision. This is also in line with reviewer #2 who recommends publication and has suggested only minor corrections. We do not agree that we should reduce or omit the discussion parts that confirm results of previous studies, since the second aim of this paper is to go more into a more detailed discussion of the chemical and physical reasons for the changes in the ozone concentrations in the present century compared to the previous and coming centuries. Reducing or omitting parts of the discussion would make it difficult for a reader to follow the argumentations and possible explanations. The other option, suggested by the reviewer, of changing the focus of the paper to discuss the differences between the 1990s/2090 results of the current and previous results would change the focus of the paper where the aim is to understand the processes. The new results in this paper are produced with an updated version of the model system, including the climate model, the air pollution model, and a more realistic scenario. The results in this paper constitutes therefore a better and more realistic background for studying the climate change impacts on air pollution levels and broadens the perspective by examining the changes in the present century compared to previous and coming centuries.

Reviewer: Furthermore the paper contains several lapses in English (for example, the correct use of 'has' and 'have' in connection with singular and plural should be

ACPD

11, C3604–C3610, 2011

checked).

Answer: We have checked the use of “has” and “have” throughout the paper and corrected where necessary.

Specific remarks:

Reviewer: The results for the 1890s are almost nowhere discussed and are not very relevant anyway, maybe they can be omitted.

Answer: Since the results in the paper show that the main changes happen in the 21st century, most of the discussions focus on this period. However, the reviewer is correct in the point that the changes in the 20th century are not described with enough detail. We have inserted more comments on this century.

Reviewer: Johnson et al. (2001): Missing reference

Answer: The missing reference has been inserted.

Reviewer: P 6814: Did the authors perform the ECHAM5 simulations themselves? Otherwise, data source should be acknowledged.

Answer: Yes – we performed the ECHAM5 simulations ourselves.

Reviewer: Fig. 9 is mentioned only once in the context with NOx on page 6118. Fig. 9, however, shows NO2. The authors should either discuss NOx chemistry or skip the figure.

Answer: The reference to Fig. 9 has been moved to the appropriate places in the article, where NO2 is described.

Reviewer: P. 6919-6821: There are a lot of commonplace remarks on chemistry or isoprene emissions which do not always appear closely relevant to the presentation of the results.

Answer: We have looked carefully through the text but have not found any remarks that

ACPD

11, C3604–C3610, 2011

are not relevant to the results, according to our opinion.

Reviewer: P. 6825: Does this mean that there are still significant concentrations of isoprene at a height of almost 5 km?

Answer: No – the higher ozone concentrations at higher altitudes originates from the increased ozone production near the surface due to increased isoprene at the surface, in general.

Reviewer: P. 6826: Today most atmospheric climate models have very simplified descriptions of atmospheric chemistry including ozone chemistry and therefore account poorly for the feedback from atmospheric chemistry to the climate system. This sentence is not exactly true anymore nowadays.

Answer: We have changed “most” to “many of the”

Reviewer: Figure 6: Maybe t-values are not useful to analyse changes in isoprene as significant changes are shown over the oceans.

Answer: The t-values are also useful to analyse the changes in isoprene over the oceans, since there is also a general increase in the levels in these areas, even though they are remote to the emission areas. However, after a re-examination of figure 6, we have changed the plotting of the middle panels showing the change in mean values between the decades. There was a white colour in the plots that was misleading and not explained and this has been removed.

Reviewer:

Language (errors in heavy print, no complete list):

Four decades in different centuries has been simulated

Since the atmospheric chemistry of most chemical compounds are highly dependent on temperature . . .

ACPD

11, C3604–C3610, 2011

the dessert of Sahara

The Arctic Ocean differs from the above pattern . . .

There are therefore a close correlation between

This study indicates that a given change in ozone concentration in the future depend on . . .

can have NOxious effects

Answer: We have corrected the language in the sentences, suggested by the reviewer.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 6805, 2011.