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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The relative importance of impacts from climate change vs. emissions change on air pollution levels in the 21st century" *by* G. B. Hedegaard et al.

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Answers to Anonymous Referee #1

Reviewer: This paper presents a very interesting study on the relative impacts of climate changes to the projected emission changes. The investigation was well organized and the results are clearly presented. The dominant forces for the changes in ozone and particulate matter (PM) in the future are identified through the modeling study, which sheds some lights on the future air quality control strategies. I have no objection to the publication of this paper and have following points for the authors to consider before the publication:

Answer: We would like to thank the reviewer for the very nice comments. In the following, we will take into account the points from the reviewer:

Reviewer: (1) The impacts of climate and emissions on the changes in ozone and PM are described in the paper. As we know very clear that the climate change and emission scenarios have many assumptions built in, it is suggested that the authors add a section on the uncertainties of the climate projections and emissions scenarios and hence the uncertainties of impacts predicted by the model.

Answer: We fully understand the concerns of the reviewer with respect to uncertainties in the climate projections and in the emission scenarios. However, as both of them are exactly projections of the future, it is rather difficult or even impossible to assess the uncertainties of these data. With respect to an evaluation of using climate data for driving a long-range chemistry transport model (CTM), this was carried out in an earlier study; see the reference Hedegaard et al. (2008) in the paper. In this study, the model results from the CTM driven by climate data from the ECHAM5 model was evaluated against measurements of different chemical species for a period of 10 years (1990ties) and compared with model results obtained driving the CTM with real meteorological data from the MM5 model. Even though the actual weather cannot be simulated in the 1990ties with a climate model in a so-called free run starting more than 100 years earlier, the results showed that the CTM gave convincing results on a monthly basis over the decade, and in some cases the results were even better than driving the CTM with the real meteorological data, using MM5. The conclusion was that it was possible to reproduce the climatological behavior of the chemical weather over a decade, using a climate model for driving the CTM. So the uncertainty with respect to the climate model and the coupling with the CTM has already been evaluated. In Section 2, line 24, we made the following comment: "The performance of the total model system with ECHAM5/MPI-OM model coupled to the DEHM model system has been thoroughly tested in earlier studies (Hedegaard, 2007; Hedegaard et al., 2008)."

Then there is the question about the uncertainty of the emission projections. In this

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case we are using the RCP4.5, which are the representative concentration pathway towards a climate, where the energy balanced has changed by 4.5 W/m2 as a global average. Since it is a projection towards a given chosen scenario, the emissions cannot be evaluated with respect to any uncertainty. In the introduction, we state: "However, it should be emphasized that nobody knows the future and that this study is to be considered as a sensitivity study and a first step in the direction of quantifying the relative importance of impacts from climate change vs. emission change in this century".

Reviewer: (2) The annual mean precipitation frequency in Figure 1 seems to have sharp meridional gradients at some latitudes, which is also quite systematic in the zonal directions. This could result in the same patterns of BC changes in Figures 4 and 5. Is this real? Need some explanations.

Answer: The sharp meridional gradient in the precipitation and precipitation frequency is a common prediction from many of the climate models, which is a result of warmer temperatures, giving rise to more evaporation and cloud cover in some regions and less in other regions. In some cases the weather systems are simply moving e.g. towards north, which is seen e.g. over the Pacific Ocean, where it is most clear, giving rise to the sharp gradients. The change in precipitation and especially in the precipitation frequency has an immediate impact on concentration levels of atmospheric particles via increased or decreased wet deposition, which are clearly seen in Figures 4 and 5. It is a real process projected by this and other climate models.

In Section 3, this is explained as follows: "Focusing on Europe the precipitation frequency is projected to decrease significantly in the Southern Europe and oppositely an increase is projected in Scandinavia, Finland, Iceland, and Greenland. More generally, the precipitation frequency is projected to increase North of about 60o N and decrease significantly in the subtropical part of the Pacific and Atlantic Ocean, the Caribbean, Mexico and the Central South America and in Western Africa."

Reviewer: (3) Most of the results are shown in the coloured figures with explanations in

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the manuscript. It would be more clear if a table is used to summarize these changes with numbers and statistics.

Answer:We find it very difficult to summarize the changes with numbers and statistics. Since changes in future concentration deposition levels are very much depending on location and regional differences, the results are shown as coloured figures, including the decadal means, the differences and a test for significance of the change in every grid cell of the model in order to see patterns in the statistics. In our opinion, it would not be possible to provide hemispheric numbers or statistics, since there are large regional differences and it are these differences that are important to address to understand the underlying processes. This can mainly be done by analyzing the coloured figures.

Reviewer: (4) PM2.5 is exclusively mentioned in the paper. How it was simulated? Would the changes in precipitation have any impacts on the removal of PM as whole? I would like to see more on the mechanisms of the impacts of climate changes on PM and PM2.5.

Answer: As explained in Section 4.2, "The total PM2.5 consists in the model of the sum of the following species: primary emitted mineral dust, black carbon (fresh and aged), organic carbon, and the secondary formed particles H2SO4, NO3− , NH4NO3, NH4HSO4 and (NH4)2SO4. Secondary formed organic aerosols (SOA) are not included in the current model setup". The changes in precipitation have a direct impact on removal of PM2.5 via wet deposition in the model.

Reviewer: (5) The Summary and conclusions section is too long and duplicates quite a lot of the main sections. It is suggested to concise it.

Answer: We have gone through the section and tried to concise it. Our purpose with the section is, however, to draw up the main conclusions from the results and discussion section. We think that it is important in this paper to summarize the main findings to help the reader to acquire the final overview of the main results and as such we believe that a section of little more than 2 pages is not too bad.

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Reviewer: (6) Reading through the manuscript, there are a number of places that need polishing on the English usage. For example, in the abstract, it said " . . .(DEHM) driven on.." while it may better be ". . .(DEHM) driven by..".

Answer: We have carefully read the manuscript and made polishing on the language and accordingly changed the text in the abstract.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 24501, 2012.

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Interactive Comment