Atmos. Chem. Phys. Discuss., 8, S6260–S6273, 2008 www.atmos-chem-phys-discuss.net/8/S6260/2008/ © Author(s) 2008. This work is distributed under the Creative Commons Attribute 3.0 License.



ACPD 8, S6260–S6273, 2008

> Interactive Comment

Interactive comment on "Influence of future air pollution mitigation strategies on total aerosol radiative forcing" by S. Kloster et al.

S. Kloster et al.

Received and published: 23 August 2008

We thank the reviewers for their constructive comments and suggestions. We hope to have addressed all raised issues in our comments on the individual reviews.

Anonymous Referee 2:

Specific major comments:

A) Model description:

The model description is broken up somewhat awkwardly between Sections 2 and 3. There are many aspects of the model description that would seem to fit more naturally in Section 2 that are withheld until Section 3, or in some cases not given at all. For instance, the use of offline oxidants should be mentioned in Section 2.2 where HAM is described. You do not adequately describe how aerosols are converted from



Printer-friendly Version

Interactive Discussion



hydrophilic to hydrophobic (relevant for the discussion of 'microphysical aging time'). There is some description later (Section 5.2), but none in the model description sections. Which variables are being nudged in your model? Any of the cloud fields, or only the 'dynamical' fields? What about water vapor?

(i) See answer to referee1 comment 1: description of sulfur chemistry using offline oxidant concentrations in model section 2.2 (ii) See answer to referee1 comment 10: description of transfer of hydrophobic to hydrophilic in the model section 2.2. (iii) See answer to referee1 comment 4: better description of nudging technique applied in simulation setup section 3.1

B) Emissions: Aerosol emissions are discussed in Section 3.1 and Table 1. But, it is hard to understand which of the emissions shown in Table 1 are included in any particular simulation. Table 2 helps with this, but does not clear up all of the confusion. Some of the values given in Table 1 do not seem to be used in any of the simulations (e.g., 'anthropogenic AEROCOM 2000'). Maybe you could add another row at the bottom of Table 1 that lists the total emissions for the 4 base simulations (1750, 2000, CLE 2030, and MFR 2030). You could also bold the individual entries in the Table that are included in those totals. An additional problem with the emissions is that some of the values in Table 1 do not agree with those given by Dentener et al. (2006a). This either needs to be corrected or explained (clearly) in the text.

This study uses AEROCOM emissions as given by Dentener et al. (2006a). We corrected the values in the Table accordingly (see comment 20 referee2). As suggested we added the emissions used in the base simulations to Table 1. Anthropogenic AE-ROCOM emissions for the year 2000 were not used in this study and we deleted them from the Table 1.

C) Comparison with previous studies: There are few comparisons of the results of this study with those of previous studies. For instance, the year 2000 aerosol budgets (Section 4.2) can be compared with the range of results presented in the Textor et al.

8, S6260-S6273, 2008

Interactive Comment



Printer-friendly Version

Interactive Discussion



2007 AEROCOM paper. You state that the -2.0 W/m2 aerosol RF from preindustrial to present is on the high end of models reported in Denman et al. 2007. What are the implications of the large negative pre-industrial to present RF for the total (gas+aerosol) forcing over this time period? There have been other projections of future aerosol radiative forcing (at least for direct forcing, possibly also for indirect) with which you could compare.

(i) Denman et al. 2007 is the most comprehensive summary of recent model estimates of the total anthropogenic aerosol effect summarizing results from 13 independent estimates on total anthropogenic aerosol RF. We can not think of any better reference. (ii) We agree that we could confront our results for the aerosol budget with other model simulations (summarized in AEROCOM, Textor et al., 2007). However, a direct comparison is difficult as our study differs in terms of the emissions used and also includes the indirect aerosol effect impacting sulfate lifetime and burden. Instead, we decided to compare our model simulation against measurements. Both referees mentioned that the manuscript is guite long. A comparison to other model results would further lengthen the manuscript. (iii) Yes, there are other projections of future aerosol radiative forcings. We acknowledged them in the Introduction of our manuscript: Several studies investigated the impact of changes in air pollution and associated impacts on radiation and climate applying anthropogenic emission forecast from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES) (Nakicenovic et al., 2000) using global climate models with varying degrees in complexity (Unger et al., 2008, Menon et al. 2008, 2008, Shindell et al., 2008, Shindell et al., 2008b, Koch et al., 2007b). Again, a direct comparison of our results to the studies mentioned above is difficult, as models use different emissions and include different complexity in the processes considered.

D) 'SO2 emissions' versus 'SO2 source': In Section 4.1, you repeatedly refer to 'SO2 emissions' in giving percent changes between simulations. Do you really mean SO2 emissions (as in Table 1) here, or are you referring to 'SO4 source' (as in Table 3).

ACPD

8, S6260-S6273, 2008

Interactive Comment



Printer-friendly Version

Interactive Discussion



Comparing the numbers given in the text, it appears that you are referring to the SO4 source, although this is extremely misleading. For instance, you state that the SO2 emissions increase by 6% in the CLE:2030 experiment. As far as I can tell (see point B above), the total SO2 emissions in 2000 are 74.14 Tg/yr, and in CLE:2030 are 77.2. This is an increase of 4%. From Table 3, though, the SO4 source increases from 70.49 to 74.85, an increase of 6%. Please clarify throughout this section (and sporadically in other sections).

We used a couple of times SO2 emission when actually referring to SO4 source changes. We corrected this throughout the manuscript (see comment E referee2)

E) Reference simulations (*PI*, present, future): The choice of reference years for showing differences and, especially, percent differences throughout the paper is unintuitive and leads to some misleading statements. For instance, in Section 4.1 you refer to 'the increase of SO2 [emissions] from pre-industrial to present day times (+55%)'. Aside from the fact that you are referring to SO4 source, not SO2 emissions (see comment *D* above), this is still confusing. From Table 3, the SO4 source increases from 31.46 in PI to 70.49 in 2000. This is a 124% increase, not a 55% increase. What you mean to say here is that PI is 55% lower than present. The usage in the paper is sloppy and misleading, and needs to be cleaned up.

We choose as a reference year the year 2000. We agree that this might be confusing for percentage changes in emissions. However, it is more intuitive when dealing with anthropogenic and future RF both referenced to the same present-day year (2000), i.e. anthropogenic RF = 2000 - PI, future RF= 2030 - 2000. Several times we accidentally used the term SO2 emissions when actually referring to SO4 source strength (sum of SO2 in-cloud oxidation, condensation of gas-phase sulfuric acid, primary emissions, and nucleation of sulfuric acid formed in the gas phase). We also realized that the Tables in the appendix (Table A1 to Table A3) refer to SO2 source strength (primary emissions as well as SO2 derived from DMS oxidation). For consistency we changed Table 1 to Table 3 now referring to SO2 source instead of SO4 source. De-

8, S6260-S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



tails on how percentage changes were derived are given in the Table captions: 'Numbers in parenthesis are the percentage difference with respect to the 2000 simulation, i.e. 2000 - PI in case of the PI experiment and EXP - 2000 for the future experiments with EXP \in (MFR:2030, CLE:2030, MFR:2030:IP, MFR:2030:DT, MFR:2030:EUROPE, MFR:2030:ASIA).' as well as in the beginning of the results chapter: 'In the following we focus on changes in the aerosol and aerosol precursor emissions, aerosol burdens and the resulting total aerosol radiative forcing (RF) relative to 2000, i.e. (2000 - pre-industrial) and (2030 - 2000).'

We checked the manuscript thoroughly when referring to percentage changes and changed the section: 'Aerosol Emissions' accordingly to:

Global annual mean total aerosol emissions are given in Table 4. For SO2 the source is the sum of primary emissions and SO2 derived from DMS oxidation. The differences of the single scenarios to the 2000 scenario are shown as zonal annual means in Fig. 1 (a-c) together with the simulated changes in the respective aerosol burden Fig. 1 (d-f). Regional budgets for all experiments and the annual mean global distribution for the 2000 experiment (2000) are given in the appendix (Table A1 and Fig. A2). Sea Salt, dust and DMS emissions are simulated interactively in all experiments. Since the nudging technique allows small variations of e.g. the simulated wind speed and temperature they vary slightly between the different experiments (less than 0.5%). We do not further consider these variations in the discussion of the results. In the CLE:2030 experiment the global annual mean SO2 source increases by 4% with reductions over Europe (OECD Europe -34%, Eastern Europe -61%) and USA (-6%) and increases in South Asia (+192%), South East Asia (+98%) and Africa (e.g. Southern Africa +0.1%, Northern Africa +16.5%). BC and POM emission decrease globally with -11% and -8%, respectively. In the MFR:2030 experiment the SO2 source and BC and POM emissions are reduced globally by -45%, -28% and -13%, respectively. The magnitude of the SO2 source reduction in MFR:2030 is comparable with the 59% lower SO2 source in pre-industrial times compared to present day times. For BC and POM emisACPD

8, S6260-S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



sions, pre-industrial values were +83% and +51% lower than present, which is much larger than the emission reductions in CLE:2030 and MFR:2030. This is due to lower BC and POM biomass burning emissions in pre-industrial times, whereas in the future scenarios they are kept constant. In the sectoral experiments the emission differences reflect the sector contribution to the total emissions. Industry and powerplant emissions dominate the total SO2 emissions while domestic and transport emissions are more important sources for BC and POM emissions. Therefore, in the MFR:2030:IP experiment, the SO2 source is strongly reduced and shows similarity with the MFR:2030 experiment, whereas BC and POM emissions show a comparable decrease with the CLE:2030 experiment. The MFR:2030:DT experiment shows only a small change in the SO2 source (comparable to CLE:2030) and BC and POM emissions are strongly reduced, similar to MFR:2030. In the case aerosol emissions are reduced over Europe according to MFR 2030 (MFR:2030:EUROPE) the SO2 source still increases globally (+0.2%) due to the increase over Asia which is not completely compensated by the decrease over Europe. In contrast, global annual mean BC and POM emission decrease (BC:-13%; POM:-9%), but to a much lesser extent than in the MFR:2030 scenario (BC:-28%; POM:-13%), reflecting that current legislation does not strongly reduce BC and POM emissions in 2030 except over Europe. In contrast, the MFR:2030:ASIA scenario shows a strong decrease of the SO2 source and BC and POM emissions (-20%, -20%, -11%, respectively), reflecting the high potential to reduce aerosol emissions over Asia assuming that all currently available aerosol emission abatements will be implemented.

Minor comments:

1. P5568: In the description of the sulfur scheme, it should be mentioned that offline oxidant concentrations are used. You should also either mention the source of these fields, or indicate that they are discussed in a later sections.

Done, see comment 1 referee1

2. P5568-5569: Mention in this section how hydrophobic aerosols are converted into

ACPD

8, S6260-S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



S6266

hydrophilic form. How much coating (of sulfate or other materials) is needed before the aerosols are considered to be hydrophilic?

Done, see comment 10 referee1

3. P5571, L4: Quantify the underestimate of observed BC concentrations.

We added values on the agreement of modeled and measured values in the Figure A1 given in the appendix which compares modeled and observed BC concentrations.

4. P 5571, L4: Give values for the lifetimes or refers to the appropriate Tables. Do you mean here that the lifetime of BC is almost identical to that of POM, or that the lifetimes are almost identical to those in the reference simulation.

We changed the manuscript to: The simulated lifetimes for BC and POM are almost identical in both studies

5. P5571, L9: Qualify your statement about 'good agreement' by referring back to the biased mentioned in the previous paragraph.

Done, see comment C referee1

6. P5571, L15-19: Which variables are being nudged? Over which altitudes?

Done, see comment 4 referee1

7. P5571, L20-25: An additional reference between the RF as calculated here and in the standard definition is the lack in stratospheric adjustment (although this has been found to be unimportant for tropospheric aerosols).

Done, see comment 4 referee1

9. P5573, L4: This is the first mention of a pre-industrial simulation. This should be discussed earlier (e.g., in the Intro) along with the other main simulations.

We changed the Introduction to: Here we focus on the year 2030, the policy relevant future, and contrast future changes with present day anthropogenic RF, defined as

ACPD

8, S6260–S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



the difference between present day and pre-industrial times. As well as the Section 3.1: Aerosol emissions to: For this study we focus our analysis on the year 2030 in comparison to present-day conditions (2000) and contrast the results with present day anthropogenic RF, defined as the difference between 2000 and pre-industrial (PI).

10. P5573, L3-6: This sentence is unclear. Indicate that the biomass burning emissions are different in 1750 versus 2000, but that the 2000 values are assumed to apply also in 2030. Mention that the production of SOA is treated via direct emissions of POM (as prescribed in AEROCOM). Also, clarify that 1750 emissions for other source categories are taken from AEROCOM (Dentener et al., 2006a).

We changed the manuscript to: Open biomass burning and natural aerosol emissions are taken from the AeroCom emission inventories (Dentener et al. 2006a and references therein) for the present-day (2000) and pre-industrial (PI) experiments. Future changes are not taken into account, i.e., all future experiments (2030) use the emissions representative for the year 2000.

11. P5573: Clarify that different oxidant fields are used for the pre-industrial, present, CLE:2030 and MFR:2030 experiments. Mention that the details are provided in the next section.

The oxidant concentrations used for the single experiments are listed in Table 2 and described in section 3.3: Description of the single experiments.

12. P5575, L6-14: Explain which sets of oxidant concentrations are used for these sensitivity-experiments.

The sensitivity experiments use MFR:2030 oxidant concentrations. This is described in Table 2 in which all experiments are summarized. (see referee2 comment 11).

13. P5575, L20: Refer also to Table 3 here.

Done

ACPD

8, S6260–S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



14. P5576, L6: Do you mean SO2 emissions or SO4 source here? See also major comment D) above. Same comment throughout this paragraph and on p5577, L14.

We are referring to SO4 source. We changed the paragraph accordingly (see comments D and E referee2)

15. P5576, L8: Explain why there is a range given for Africa but not for the other regions. Presumably this refers to the 4 different Africa regions shown in Table A1 (Northern Africa, Western Africa, Eastern Africa, and Southern Africa; note that the colors for these regions in Fig. A3 are almost impossible to distinguish). In the case of Europe, though, you cite the value for 'Europe OECD' rather than 'Eastern Europe', 'Europe Reg. Exp.' (which is never defined). Why? Elsewhere in the text (e.g., Section 4.3, p.5581) you seem to use the 'Europe Reg. Exp.' region instead. Similarly, the value you give for 'North America' in the text is listed in the table as 'USA'. Be consistent in the names you use for regions. As an additional point, why does Table A1 give 'SO2 source' while Tables 3-5 give 'SO4 source'. This is confusing.

We changed the text accordingly to: In the CLE:2030 experiment global SO2 source increase by 4% with reductions over Europe (OECD Europe -34%, Eastern Europe -61%) and USA (-6%) and increases in South Asia (+192%), South East Asia (+98%) and Africa (e.g. Southern Africa +0.1%, Northern Africa 16.5%).

'Europe Reg. Exp. and Asia Reg. Exp.' are now defined in section 3.3.: Description of the single experiments.

Tables 3-5 now list SO2 source instead of SO4 source (see comments D and E referee2) consistent with the Tables given in the appendix.

16: P5576, L11-12: Confusing. The SO4 source increase by 124% from PI to 2000. You mean here that PI is 55% lower than present (see major comment E above.). Instead, you can say just that the MFR:2030 SO4 source is reduced nearly to PI levels (33% higher).

ACPD

8, S6260–S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Done, see comments D and E referee2.

17: P5576, L13-14: Again, confusing. See previous comment. Also, these POM values do not match up with Table 3. Correct values here or in Table.

Corrected

18: P 5576, L23: But, Table3 shows a 2% decrease in the SO4 source in MFR:2030:DT vs. a 6% increase in CLE:2030. Rewrite the sentence.

Done, Table now refers to SO2 source (see comments D and E reviewer2)

19: P5577, L14: Do you mean 'emissions' or 'SO4 production' here?

Done, see comments D and E referee2 above.

20: P5578, L8: Again, confusing. The AOD actually increases by 34% from PI to 2000. The 25% you refer to is the 'decrease' of AOD from 2000 to PI, i.e., (PI-2000)/2000 *100%= -25%.

Corrected

21: P5579, L17-19: The RF also differs from the standard definition by not including stratospheric adjustment, but as mentioned above this is probably not important for aerosols. Also, mention that you calculate RF at TOA rather than the tropopause.

Done, see comment 4 referee1

22: P5579, L21: Change 'reflects' to 'indicate changes in' to avoid any confusion.

Changed

23: P5580, L16: The TOA RF perturbation in MFR:2030 is given as 1.13 W/m2 (not 1.03) in Tables3, 4, and A1 and in Figure2a.

This is a typo: we changed the value from 1.03 to the correct value of 1.13 W/m2 in the text.

ACPD

8, S6260-S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



24: P5581,L4-5. This sentence has its sign flipped.

We corrected the revised manuscript accordingly, see referee1 comment 14.

25: P5581, L6-8: Table A1 shows that the RF over Europe Reg. Exp is +2.93 W/m2 in MFR:2030 and +1.932 in MFR:2030:Europe. That means that RF in MFR:2030 is 52% higher (not 34%) than in MFR:2030:Europe. Also, you need to define Europe Reg. Exp. somewhere.

The values in the Table A1 are correct. We changed the text accordingly (see referee1 comment 14). 'Europe Reg. Exp.' and 'Asia Reg. Exp' are now defined in section 3.3.: Description of the single experiments (see comment 15 referee2 above).

26: P5581, L15: If you are referring to the 'Asia Reg Exp.' region here, then the increase in RF in MFR:2030 versus MFR:2030:ASIA is 23% (not 20%) according to Table A1.

Done, see comment 24 referee2

27: P5582, L25-27: Clarify that you mean here small impacts versus the standard MFR:2030 and CLE:2030 runs (not small impacts versus 2000)

We changed in the manuscript to: If oxidant concentrations would remain identical to present day conditions, a situation that would be roughly representative for the absence of further mitigation measures to reduce ozone precursor emissions, we simulate only small impacts in the global annual mean SO4 burden (Table 4) for both aerosol and aerosol precursor emission scenarios (CLE 2030 and MFR 2030) compared to experiments in which oxidant concentrations are changed in accordance with the aerosol and aerosol precursor emission scenarios.

28: P5584, L17-20: Expand on the treatment of microphysical aging in the model earlier in the paper, i.e., in the model description section(s).

Done, see comment 10 referee1 above.

8, S6260–S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



29: P5587, L17: Indicate that the RF perturbation is versus 2000.

We changed to: Overall, this leads to a very small global annual mean positive total aerosol TOA RF of +0.02 W/m2 compared to present-day conditions.

30: P5587, L26-28: This sentence is unclear. First, as mentioned in an earlier comment, applying MFR in Europe vs. the CLE:2030 scenario produces a small 'decrease' in the RF (-0.02 change, from +0.02 to 0.00). Since you already gave the values for MFR:2030:EUROPE and CLE:2030 separately in the proceeding few sentences, I would suggest cutting this sentence entirely. Same point concerning the final sentence of this paragraph. Try not to keep switching between Europe and Asia in this paragraph. First, discuss Europe fully, then Asia.

Done, see comment 18 referee1

31: Table 1: Several of the AEROCOM values do not seem consistent with the values given by Dentener et al. (2006a). For instance, you list anthropogenic emissions for 1750 as 2.0 Tg/yr for POM and 0.8 TgS/yr for SO2. Dentener et al. seem to list these values as 1.56 Tg/yr and 0.06 TgS/yr, respectively. Minor discrepancy for SO2 from natural sources (14.8 vs. 14.6). Explain. Also, as mentioned above (major comment B), it would help to indicate more clearly which values in Table 1 are used in the simulations.

These are typos in the table. We used for the pre-industrial simulation the emissions as given in AEROCOM (Dentener et al., 2006a) and corrected the values in the table accordingly.

32: Table 3: The SO4 source percent change for MFR:2030:DT should be -2%, not +2%.

We changed that.

33: Table 3: What do you mean by 'transfer of the hydrophilic modes to the hydrophobic ones'? Do you mean chemical conversion of hydrophobic to hydrophilic? Explain more

ACPD 8, S6260–S6273, 2008

> Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



clearly in the text how this is calculated.

Done, see comment 10 referee1

34: Tables 4-5: These tables repeat a lot of information from Table3. I would prefer to see these tables combined into a single table (using a consistent base year for the forcing perturbations). Right now, it is unclear why certain information is given in one table vs. another. Why are some of the rows in Table 3 left out from Tables 4-5?

Table 3 includes information about the base simulations, whereas Table 4 and Table 5 describe the additional experiments used for the sensitivity studies and compares them to the relevant baseline scenario, thereby, listing only the relevant parameters discussed in the text. We prefer to keep these informations in separated tables rather then merging them together.

35: Table A1: You need to define 'Europe Reg. Exp', 'Asia Reg. Exp.' Also, be more clear about which regions you are referring to in the main text.

Done, see comment 15 referee2

36: Figure 2: It would be nice to show some of these results as lat-lon maps instead of just zonal means, particularly for the most important. Those plots would probably be a higher priority than the current Figures 3 and 4 (which could be moved to supplementary material).

Done, see comment B referee1

37: Figure 3: You could plot this Figure in percent changes instead of absolute. That might give more useful information.

Table A3 in the appendix list the differences in percentage for several world regions. Therefore, we would rather stick to the absolute values for Figure 3.

38: Figure A2: Are the sulfur emissions given in terms of mgS/m2/s or mg(SO2+SO4)/m2/s? Similarly for the burden (mgS/m2 or mgSO4/m2).

8, S6260–S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



It is mg(S) we added this to the caption.

all typos were corrected in the revised manuscripts.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 5563, 2008.

ACPD

8, S6260–S6273, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

