

## ***Interactive comment on “Megacity ozone air quality under four alternative future scenarios” by T. M. Butler et al.***

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We thank both anonymous referees for their overall positive assessment of our manuscript and their helpful comments. Based on these comments we have made changes to our manuscript which we believe have enhanced its quality. Details of the changes and responses to points raised by the reviewers are listed below.

Anonymous referee #1

General comments

P141L1-17

Referee #2 has also highlighted similar issues in their general comments. The re-

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sponse to both reviewers is given here. In order to respond to these comments we have altered our discussion in Section 3 to more explicitly describe the bias towards NO<sub>x</sub> limited conditions expected from using a coarse model resolution, and we have mentioned that these biases are likely to be strongest in our megacity grid cells. We have also clarified the methods by which Wild and Prather (2006) quantified these biases. Referee #1 also makes the interesting point that it would be good to know specifically how the sensitivity of ozone production regimes to megacity emissions perturbations varies with model resolution. We agree with this, but we would not like to speculate on this without actually having done any simulations investigating this; unfortunately it was not possible to repeat the suite of simulations at higher resolution given the resources available for this study.

P145

We agree that the figures summarising data from many different cities would be better presented as means and standard deviations. Reviewer #2 also suggested this, and we prefer his suggestion of presenting the standard deviations as error bars on the mean seasonal cycles for each latitude band. The figures have been modified accordingly.

P148L20-25

We already have some discussion about the applicability of the RCP scenarios for air quality studies in Section 2.1, but the reviewer is correct that this should be mentioned again in the conclusions. We added this to the middle of the final paragraph, where we also reiterate other limitations of the emissions we have used.

P131L21-22

The reviewer is correct that none of the referenced papers include a detailed long term trend analysis of the effects of background ozone on urban air quality. They do however identify effects of background ozone, and it is also fair to say that urban emission controls have improved local urban ozone air quality. To respond to this reviewer com-

C1835

ment we have toned down the definitiveness of our statement in the introduction, and we have expanded our discussion of this issue in the conclusions. We also reworded a similar sentence in the abstract.

#### Specific comments

P131L6

We agree that since previous work has minimised the global impact of megacities, that this statement about the potential impact of megacities seems out of place. To convey the point that this is still an area of scientific interest, we have instead mentioned that recently, two major EU research projects have been funded to investigate these issues.

P131L17

We have added text explaining that toxic pollutants are defined by the US Clean Air Act.

P132

We do not understand why paragraphs 2 and 3 here are interpreted to be contradictory.

P133L15

Yes, the "coupling" in CMIP originally referred to coupled ocean- atmosphere models, and has now grown to include coupled chemistry- climate models. For the CMIP5 project, not all models necessarily include the chemistry component. We have reworded this sentence to better reflect this context.

P133L20-23

We have not claimed that climate co-benefits contribute to ozone precursor reductions in RCP-8.5. This is clearly attributed to RCP-2.6 in our manuscript. We have slightly reworded our explanation to make this clearer. Additionally the reviewer has requested more information on the technological measures used in the scenarios. We have added

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this to the second paragraph of the subsection, where we now mention that RCP-8.5 includes a continuing reliance on fossil fuels, and the RCP-2.6 includes efficiency improvements, capture and sequestration of carbon dioxide, and increased use of nuclear and renewable energy.

P135L23

Yes, all primary NO<sub>x</sub> is emitted as NO. We added some text to Section 3 to make this clear.

P136

We already had a sentence early in this paragraph explaining that the megacity grid cells are based only on 2005 data. In order to emphasise this even more, we have added another sentence to the end of the paragraph repeating this point and making it clear that the same mask is used in all cases.

P138L5

We agree that it would be of some interest to plot the megacity proportion of total anthropogenic emissions from RCP-8.5-P in Figure 3, although none of the arguments we make in the paper depend specifically on this. We are reluctant to do this, however, because we do not introduce RCP-8.5-P until after our discussion of Figure 3. Adding this information to the figure would involve either a reorganisation of the sequence of material in the paper, or a forward reference, both of which would detract from the readability.

P144L2

We have added text generalising this point to all scenarios created using proportional downscaling, and we have also added text before this clarifying our additional explanation of why the local megacity impact is especially high in RCP-2.6.

#### Minor comments

C1837

We have modified the table so that two significant figures are use consistently.

P141L2

We fixed this typo.

P141

We agree with the suggested change in the ordering of the paragraphs, and have made this change.

P142

We have added appropriate subsection headings.

P144

We have removed this stray word, and clarified further that the percentage change is relative to the base run.

P145

We have added an explicit expression for the percentage change.

Figures

We agree that some of the figure titles can seem somewhat cryptic. In order to address this, we have removed the figure titles from Fig. 5 (the panels are already explained well in the caption), and updated the titles of Figs. 6, 7, and 8 to be more human readable. For technical reasons the titles to Fig. 4 were not updated. If desired, we can also update these.

Supplementary Figures

We have a added a short note to the caption for each of figures S1 to S3 explaining how to read the color scale.

Anonymous referee #2

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General comments

The first part of the general comments from reviewer #2 brings up some very similar points to the first general comment of reviewer #1. Our response to both reviewers regarding this issue can be found in our response to reviewer #1.

Regarding the rest of this general comment, we disagree with the reviewer that any definitive conclusions about the behaviour of individual cities in our redistribution analysis can be inferred from our Figure 5. Indeed, we caution in Section 4 (P146L13, discussion version) that focusing on any particular individual city in an analysis such as ours is unlikely to be useful.

Specific comments

P130L13

We changed "different" to "simpler", and added text to make it clear that the result of this difference is an increase in the computer emissions associated with the megacities.

P135L23

Our treatment of the methane mixing ratios is described in Section 3. We have added some extra text to this section to make it clearer that methane mixing ratios are fixed throughout the entire model domain.

P135L28

We have changed this around to show that the method is less dependant on the subjective judgement of the person constructing the megacity mask.

P136L5

We understand from ACP style guidelines that manuscripts in preparation are to be referenced only using footnotes, and not included in the main list of references. We added the reference for the Collins World Atlas to the reference list.

C1839

P140L21

It is not clear to us why this subsection is unnumbered. It is declared with the same standard latex subsection command as all other subsections in the manuscript. This appears to be a matter for the typesetting staff at the journal to investigate. We thank the referee for pointing this out, and we will make sure that this is fixed during the proofreading stage.

P141L27

It is not clear to us what the reviewer means by "harmonising (megacity emissions) over the country as a whole", but we suspect that this is likely to be as arbitrary a choice as redistributing the emissions as we have done so in this study. Regarding the choice of the 25% emissions reduction, we added some text explaining this with reference to the literature at the end of this subsection.

P144L9-10

The redistribution of emissions involved in creating RCP-8.5-P from RCP-8.5 is more extensive than the redistribution of megacity emissions in our redistribution runs. This provides a much better illustration of this effect, which is what we are actually highlighting in our conclusions. In order to make this clearer in the text we have expanded our discussion of Figure S4, and explicitly drawn attention to the similarity between RCP-8.5 and RCP-8.5-P in this figure, with discussion of the relevance to radiative forcing.

P146L19

The 0.84% figure is taken from Table 2, and we have added an explicit mention of this number to the text describing this table. It is not immediately clear to us how it would be useful to compare this number, the effect of a wide range of sources which are co-located in small geographical regions, with numbers from other studies such as QUANTIFY which describe the effects of single source categories which are spread over large geographical regions. We do agree with the reviewer that comparison of

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different approaches for analysing megacity impacts would be interesting, but we believe that a comprehensive approach to this is beyond the scope of our study; we have explored one possible approach, and future studies may choose differently.

P146L21

The 6% figure for NO<sub>x</sub> applies equally well to present day anthropogenic emissions all ozone precursors, namely CO, NO<sub>x</sub>, and NMVOC, as seen in our Figure 3.

P146L24

"spatially explicit" describes more specifically the point being made here. We have changed the text appropriately.

P147L21

This is related to the 4th general comment of referee #1.

P148L11

We agree completely with this suggestion by the reviewer, but we do not want to dilute our message by calling for a list of technical options for emissions specification. We believe that by calling for "emissions scenarios which are geographically resolved enough to be useful at small scales", that we make our point clearly.

P155

We have added a conversion factor to Dobson Units in the caption.

Figures

See the second general comment from reviewer #1.

Typos

All fixed. Thanks.

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Interactive comment on Atmos. Chem. Phys. Discuss., 12, 129, 2012.

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