

Interactive comment on “The effects of global change upon United States air quality” by R. Gonzalez-Abraham et al.

R. Gonzalez-Abraham et al.

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We appreciate the referee for his/her constructive and thorough review. We have revised the manuscript according to the referee's comments. During the revision, we learned there were bugs in CMAQv4.7 in processing emissions, as described here: www.cmascenter.org/cmaq/documentation/4.7.1/RELEASE_NOTES.txt. Accordingly, we have re-run all simulations using CMAQv4.7.1, resulting in substantial changes to the PM_{2.5} section. Changes in ozone also occurred as a result of upgrading to CMAQ 4.7.1 due a combination of updates in emission, advection and plume rise emission modeling. Most notably, a larger increase in ozone in coastal urban areas is projected as a result of changes in US anthropogenic emissions. We believe the manuscript

C13399

has been much improved in addressing comments by both referees and updating the manuscript to reflect the new simulations. Our detailed responses to Referee #1's comments (in italics) appear below.

After the General comments, every comment is numerated. The response is immediately below the comment. The revised manuscript is attached.

General Comments

This paper describes a climate model downscaling study to investigate the impact of future climate change (following the IPCC A1B scenario) on US air quality. The authors find that daily maximum 8 h average ozone (DM8O) will increase by 2-12 ppb in the US due to increased temperatures, enhanced biogenic emissions, and land use changes, which will overwhelm the reductions in DM8O that would have happened from reductions in US anthropogenic emissions in the absence of climate change. They also find that PM_{2.5} levels are expected to increase 2-4 $\mu\text{g m}^{-3}$ in the Southeast US and nearby regions due to enhanced biogenic emissions and land use changes. This is a well-written paper on a scientific question relevant to ACP. The methods are valid and clearly outlined, as are the modeling experiments performed. Substantial conclusions are reached that are generally supported by the model results. There are a few places where the discussion is confusing or not supported by the results presented, and the tables need some work, but overall I recommend publication after minor revisions to address by concerns below.

Response

We appreciate the reviewer's positive comments. We have revised the manuscript according to both referees' comments to have more clarity in the text and updated figures and tables. Below we address Referee #1's comments directly.

Minor Comments:

1) P31844, L13-14: Since you mention evaluating the impacts of Asian emissions as

C13400

a goal of the study, you should also include your findings on their impacts on O3 and PM2.5 in the abstract.

We have revised the abstract to include: “The model predicts an average increase of 1-6 ppb in DM8O due to projected increase in global emissions of ozone precursors.”

2) P31853, L8-11: You say MARKAL was used to get growth factors of NO_x, SO₂, and PM_{2.5}, but then mention the use of CO₂ factors as well. Should CO₂ be on the initial list as well?

The Referee is correct. We have revised the manuscript to include CO₂.

3) P31853, L10-11: I'm not sure that it is appropriate to use CO₂ growth factors for CO, NH₃, VOCs, HCl, and chlorine. I understand doing it in the absence of other data, but how realistic do you think it is that CO will increase proportionally with CO₂ even with future control technologies being implemented to reduce NO_x and SO₂ emissions. This gives a 70% increase in CO and 20% increase in NMVOCs in the Midwest – how realistic is that? And how does this affect your results?

We agree that using CO₂ growth factors for CO and VOC is not the most appropriate. Historically CO emissions and concentrations have been decreasing while CO₂ emissions are increasing (<http://www.epa.gov/airtrends/carbon.html>). Also, for the mobile sources, the CO and NMHC emissions will either level off or will continue decreasing (McDonald et al., 2013, DOI: 10.1021/es401034z). Therefore, increase in CO emission as presented in this manuscript means higher ozone (less reduction from the current decade) in urban (high-NO_x) areas in comparison to a projection with CO-specific growth factor. We have added text to this section to note this caveat. We have added to section 3.3.1: “The smaller reduction in ozone concentrations between the future and the current decade in comparison to Nolte et al., (2008) is likely to be a consequence of the increase in VOC and CO emissions from business-as-usual scenario of ESP v1.0 which uses CO₂ as a surrogate for growth factors for CO (Loughlin et al. 2011).”

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4) P31857, L12-16: You are really stretching the words “majority” and “most” here – the results in Figure 6 don't look all that great. The claim that PM_{2.5} meets the guidelines for 4 regions seems false to me –by my eye 5 of the PM_{2.5} results fall outside the weaker bias and error constraints. I would reword this section to be a little more accurate about the model performance.

Note that due to the lack of speciated PM data for our period of simulation, we have removed the section on model performance for speciated PM (the observed data in the ACPD version were from 2003-2008 and we believed is not representative of our period of simulation). Also, the PM_{2.5} section changed substantially after the new simulations were performed.

5) P31860, L15-22: This paragraph confused me on my first read-through, as you discuss the increases in isoprene, monoterpenes, and overall BVOCs all in the first sentence. I'd try to separate out this discussion, and add a total BVOCs bar to Figure 3 as well. It is also not clear when you say “biggest increase” if you mean biggest percentage increase or biggest absolute increase.

In Figure 3, having isoprene and monoterpene emissions as separate bars is useful to aid the discussion of biogenic SOA; however, we don't think it is necessary to include another bar in Figure 3 for total BVOC because the change in BVOC emissions is dominated by changes in isoprene emissions. For clarity, we have modified the text to read: The model projects bigger percentage increase in monoterpenes than isoprene across the domain; however, total isoprene emission is an order of magnitude higher and thus dominates the changes in total BVOC. The increase in total BVOC ranges between 17% and 45%. The only region that is projected to have reduced total BVOC emissions is the Northwest, where the model simulates a 7% reduction in isoprene emissions (Figure 4) that in absolute amount is greater than the 20% increase in simulated monoterpene emissions.

6) P31861, L9-10: I think this sentence on monoterpenes belongs in the next para-

C13402

graph. Also, you say “because of higher across the domain” – higher what?

We have rearranged the text in Section 3.2 for better clarity, and the sentence referred to by the referee is no longer in the text. Also, please note that the section has changed drastically.

7) P31863, L8-9: Cloud cover only increases in the Northwest and Central regions, correct? Can you make that clear here?

The reviewer is correct that the increase in cloud cover is in the Northwest and parts of the central region (western Montana). We have modified the text to read: “The reductions in DM8O concentrations in the Northwest resulted from an increase in cloud cover and lower solar radiation reaching the ground, and resulting in a reduction in photochemistry.”

8) Comment from Referee. P31864, L1-6: I'd like to see more discussion here about how the emissions differ between this study and the previous ones and how the climate simulations differ. Some of this information is in section 2, but it would be nice to restate it here to make the discussion of the results clearer.

As requested by the reviewer, we have added more discussion to the text. First, the reference was corrected to be Nolte et al. (2008) instead of Leung and Gustafson (2008). We now have "However, the difference in geographical features of DM8O changes with Nolte et al. (2008) and Tagaris et al. (2007) suggests that the source of disparities resides in the simulated regional meteorological fields resulting from different global climate models, regional climate models and the methods used to estimate emissions from biogenic sources. We used the ECHAM5 global climate model results while both Nolte et al. (2008) and Tagaris et al. (2007) used results from the GISS global climate model. For regional climate simulations, both Nolte et al. (2008) and Tagaris et al. (2007) used MM5 while we used WRF here. In contrast with Nolte et al. (2008) and Tagaris et al. (2007) who use the BEIS/BELD3 (Hanna et al., 2005; <http://www.epa.gov/ttn/chief/emch/biogenic/>) tool to compute biogenic emis-

C13403

sions, this investigation estimates the biogenic emissions with MEGAN v2.04. MEGAN v2.04 generally predicts higher isoprene emissions than BEIS (Hogrefe et al., 2011; Sakulyanontvittaya et al., 2012). Hogrefe et al. (2011) shows that for the Northeast, MEGAN leads to higher DM8O by upwards of 7 ppb using 2005 anthropogenic emissions; however, under a scenario by which anthropogenic NO_x emissions were reduced by ~60%, difference in DM8O was generally 3 ppb because of greater sensitivity to NO_x emissions when MEGAN was used."

9) P31864, L11: Please be quantitative about the size of the decrease in DM8O you are discussing here.

We have now included "2 to 4 ppb" in the text.

10) P31864, L18: Please be quantitative about the size of the reduction in the VOC to NO_x ratio and the depletion of DM8O you are discussing here.

We have revised the text to explain the change in BVOC and NO_x emissions under the land use change scenario instead of VOC to NO_x ratio: “When land use changes are included along with biogenic emissions (Simulation 3), the increase in BVOC emissions is projected to be less, while NO emission is projected to increase in areas where natural vegetation is converted to cropland. This combination leads to higher DM8O in Simulation 3 than Simulation 2 (Simulation 3; Figure 12d).”

11) P31864, L21: The reduction of BVOC emissions due to land use changes (discussed on P31861, L7-9) also plays a role here, right?

Yes, there is a decrease in BVOC emissions and an increase in NO emissions where natural vegetation is converted to cropland. The text has been updated to reflect this. See response to comment above.

12) P31864, L28: Instead of saying “mostly” can you be quantitative?

We revised the sentence to be more quantitative. The sentence now reads: “The increase in DM8O is mostly due to an increase in global emissions of ozone precursors

C13404

from the semi-hemispheric domain, which contributes to an increase of 2-6 ppb under current climate conditions (Fig. 13f)."

13) P31865, L13-15: These two statements are not clearly supported by the results in Figure 12. In Figure 12f it looks like Asian emissions lead to a very slight increase in the southern half of the US and very slight increases in the northern half, with no reason to single out the western US as a homogenous group. The impact of climate change and biogenic emissions in Figure 12c seems to increase PM_{2.5} throughout the US rather than increases and decreases in different regions.

We had misplaced text on ozone in this section. This error has been corrected in the revised manuscript. The line now reads as follows: "Changes in global emissions do not have a significant impact on PM_{2.5} concentrations, while changes in the climate and biogenic emissions can lead to both increases and decreases in PM_{2.5} depending on the region."

14) P31866, L1-2: I think you should explicitly state here that your results for sulfate are different than Avise et al. (2009).

This section has been re-written to reflect the results of new CMAQv4.7.1 simulations after discovery of ammonia emission bugs in CMAQv4.7.

15) P31866, L23: Why is there no discussion of aerosol ammonium here? The effect of the boundary conditions on ammonium is huge in Table 3 and should be addressed in the text.

We have revised the PM_{2.5} section to reflect the new simulation results and include discussion of ammonium.

16) P31867, L1: Can you be quantitative instead of saying "insignificant"?

The line now reads as follows: ". . .the effect of climate change alone (with no change to biogenic emissions) on total PM_{2.5} concentrations over land is a change of less than 1 $\mu\text{g m}^{-3}$ "

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17) I think you need to discuss the increases in SOA in the Northwest region here – SOA increased with increases in BVOCs, but sulfate decreased, in contrast to the other regions that had negligible changes in sulfate with increased BVOCs.

The decrease in sulfate with increasing BVOC and SOA is due to the competition between BVOC and SO₂ for OH. The text now includes: "The smaller increase or absolute reduction in sulfate in comparison to the climate-only case is due to the competition between BVOC and SO₂ for the availability of OH, which is an oxidant for both."

18) P31869, L24: The "positive influence (reduced concentrations)" phrasing is confusing, consider rewording this to make what you mean clear.

The text now reads: "Decreases in future US anthropogenic emissions of ozone precursors are the only consistently beneficial influence that improves the air quality in the US; updated assumptions to generate scenarios of future US anthropogenic emissions may show even more positive influence."

Sections:

19) Section 4: You should be as quantitative as possible about the magnitudes of the impacts here, as you are in the abstract.

Our main aim for the conclusion section is to focus on the influence of each individual attribution within the context of one single future scenario (the combined changes), rather than summarizing the individual contributions quantitatively.

20) P31870, L3-5: Here I'd stick to the regions you defined in Figure 3 and avoid less specific phrases like "East regions" and "regions with high biogenic emissions."

Text has been edited to reflect referees comments: ". . .2) climate changes (namely, increased temperatures and solar radiation) which increase ozone concentrations in the Central, South, Midwest, Northeast and Southeast regions of the domain; and 3) increases in US BVOC emissions which also increase ozone concentrations in regions with high biogenic emissions such as the South, Midwest, Northeast and Southeast"

C13406

Figures and Tables

21) Table 2: This is like Table 5 for PM2.5, but where is the equivalent of Table 3 for DM8O? I'd suggest adding a table with similar quantitative results for each region.

We agree with referee's comment. A new Table 2 with the percentage change in DM8O from each scenario has replaced the old Table 2; and a new Table 5 with the percentage change in PM2.5 has replaced the old Table 5.

22) Tables 2-5: It's not clear in these tables what the scenario names in the column headings mean. Does "BVOC" include climate impacts, so that it is Scenario 2 minus Scenario 0, or does it only look at the impact of BVOCs on top of climate, and so is Scenario 2 minus Scenario 1? The same question applies for the land use changes, which aren't listed in Tables 2 and 5 but are listed in Tables 3 and 4 as BVOC future land use". Is this Scenario 4 minus Scenario 3, 2, 1, or 0? Please clarify this in footnotes in Table 2 and then use consistent definitions for all other tables.

The original Tables 2 and 5 have been replaced with tables showing percentage changes of DM8O and PM2.5. The new Tables 2 and 5 as well the original Tables 3 and 4 now have column headings listing the simulation numbers consistent with those of Table 1.

23) Table 4: You have a row called "SOA" – does that mean these results are only for SOA and not primary organic carbon? Doesn't this contradict your caption? Are the POC results just missing?

The caption should state only secondary organic aerosol. The table caption has been corrected.

24) Figure 3: Add a bar for the percentage change in total BVOCs in each region as well.

Because total BVOC is dominated by isoprene, percent change in total BVOC is very similar to percent change in isoprene. Therefore, we do not think it is necessary to add

C13407

an additional bar for BVOC.

25) Figure 5: Add a legend to the box and whisker plot as in Figure 4.

The figure has been updated to include a legend. Note that the original Figure 5 is now Figure 6.

Typos and Technical Corrections

26) P31856, L6: I think you mean Figure 11a, not the top of Figure 10. And I think this should be renumbered Figure 6, as it comes after you mention Figure 5 but before you mention Figure 6.

The reviewer is correct about the typo. The number is now Fig 12a in the revised manuscript. We have kept the figure location because it is discussed most heavily in the results section later in the manuscript.

27) P31856, L14: I think you mean Figure 12a, not the top of Figure 11. And I think this should be renumbered Figure 7.

The reviewer is correct about the typo. The number is now Fig 13a in the revised manuscript. As noted in the above comment, we prefer keeping this figure in its current position because it is discussed most heavily in the results section later in the manuscript.

28) P31858, L21: "the result of" instead of "resulted of" We have corrected the error.

29) P31864, L11: "The decrease", not "this decrease" We have corrected the error.

30) P31865, L24: I think you mean Table 3, not Table 2. And shouldn't the Southeast region also be in this list? Yes, Southeast has been added to the list

31) P31867, L14-15: You can't say "in all regions" and then discuss an exception. Try "in nearly all regions" and "The lone exception." We have corrected the error.

32) P31868, L8: Just reference Figure 12c here, and then reference Figure 12d in L11

C13408

below. We have added the figure references in the text. (The relevant figures are now numbered 13c and 13d.)

33) P31868, L11: Shouldn't the Southeast region also be in this list? We have corrected the text.

34) P31869, L2: Remove comma after "monoterpene" We have corrected the typo.

35) P31870, L28: "intended to", not "intended so" We have corrected the typo.

36) P31871, L1: Typo, remove the "7". This was an error introduced during typesetting.

37) P31871, L3: "take" not "takes" We have corrected the typo.

38) P31871, L3: The semicolon should go before the word "and" not after. We have corrected the typo.

Please also note the supplement to this comment:

<http://www.atmos-chem-phys-discuss.net/14/C13399/2015/acpd-14-C13399-2015-supplement.pdf>

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 31843, 2014.