

Response:

We are so grateful to the reviewer for the comments that helped us further improve the manuscript. We really appreciate the reviewer's thorough advice and comments, as well as the precious time. For detail, please refer to the responses below.

The reviewer's comments are in black and the responses are in blue. If responses are from the revised manuscript, they are in italic.

1) There is some repetition in text in section 2 and section 3. It would be clearer to have all the text pertinent to dynamical downscaling in section 3. In section 2, there is rather detailed text on the CESM model. There is also detailed text describing how CMAQ is driven by initial and boundary conditions from CAM-Chem. However, there is no text explaining the methods of coupling between CESM and WRF to produce future climate at 12km horizontal resolution. This is likely to have been the most challenging aspect of the study. Hence text should be added to section 3 to describe how WRF is driven by CESM. Perhaps both WRF and CMAQ are driven by 3 hourly outputs but it would be useful to state this. If space is short some of the more detailed text in section2 on model components could be removed.

Response:

Thanks to the reviewer for the helpful suggestion. Following the reviewer's advice, we moved the text pertinent to dynamical downscaling to section 3. The reviewer pointed out the importance of coupling between CESM and WRF. We totally agree with the reviewer, thus we added more descriptions on climate downscaling and also stated that three hourly CESM outputs were used to drive WRF. Since the details on climate downscaling have been described in our previous study (Gao et al., 2012), we only briefly explained the climate downscaling. The revised description (Page 7, Line 189-197) is shown below:

Dynamical downscaling is a technique that uses the outputs from global climate or chemistry models to provide the initial and boundary conditions for the regional models. In this study, three hourly global model outputs from CESM and CAM-Chem are used to provide the initial and boundary conditions for regional models WRF and CMAQ, simulations, respectively. WRF outputs are further used as the meteorological input for CMAQ. The detailed climate downscaling methodology from CESM to WRF has been described by Gao et al (2012). Thus, only chemistry downscaling methodology was discussed in detail here.

Gao, Y., Fu, J. S., Drake, J. B., Liu, Y., and Lamarque, J.-F.: Projected changes of extreme weather events in the Eastern United States based on a high-resolution climate modeling system, *Environ. Res. Lett.*, 7, 044025, 2012.

2) Why were different period lengths chosen for the present-day (4 years) and future (3 years) simulations? This is rather surprising. Furthermore, the sentence "while future climate in the 2050s potentially captures enough climate change" is vague. Given that there are only 3 years for the future simulation period more evidence should be given that the climate change signal in ozone is clear and greater than that due to inter-annual variability. Since the CAM-Chem results cover the continuous period from 2001 to the end of the 21st century it should be easily possible to show that the climate change is captured in this subset of years.

Response:

Due to the computational issue, we planned 3 years (2001-2003) in the present climate and 3 years in future (2057-2059) at the beginning. However, considering the start year of RCP scenarios is 2005, we extend the present to the year right before the start of RCP scenario in order to cover the present period in 21st century before RCP scenarios. Thus, we have 4 years at present and 3 years in the future climate.

Since the reviewer thinks the description of "while future climate in the 2050s potentially captures enough climate change" is vague, we deleted the following sentence.

"The selection of the present climate (2001-2004) considers the closest climate period before the start year (2005) of the RCP scenarios, while future climate in 2050s potentially captures enough climate change."

As the reviewer advised, we also compared the O₃ concentrations in both 10-year and 3-year periods to test the representation of the subset of 3-year for the 10-year period. The 10 year (2050-2059) global mean surface ozone concentrations under RCP 8.5 and RCP 4.5 are 30.995 ppbv and 27.482 ppbv, quite close to the 3 year mean for RCP 8.5 (31.314 ppbv) and RCP 4.5 (27.479 ppbv), indicating the climate change signal was captured in this subset of years.

3) Fig 2 may well be useful but it is unclear what is exactly shown – are these daily or 3 hourly fields, and why there would be differences other than those due to interpolation between the different model grids? It would be useful to show how the ozone field in CMAQ evolves away from the boundary.

Response:

We thank the reviewer for pointing out the unclear statement. Fig. 2 shows one hour boundary conditions in CAM-Chem and CMAQ. This figure is used to demonstrate the four boundaries in CAM-Chem and CMAQ are consistent with each other. The reason why CAM-Chem grids are not on a straight line is because we search the grid cells in CAM-Chem closest to the CMAQ grid. We only shows one hour as an example, and every three hourly, the boundaries between CAM-Chem and CMAQ are consistent as well.

4) Fig 3 and associated text is only useful if intercontinental transport effects are discussed in greater detail. Otherwise a map showing and text describing emission changes in the US region is more relevant.

Response:

The figure has been revised (Page 8, Line 230-237) to include only US region and the relevant descriptions have been revised as well, which are shown below.

Fig. 3 shows the distributions of emission differences by the end of 2050s compared to present condition. In both the RCP 4.5 and RCP 8.5 scenarios, the mean emissions globally were projected to decrease (Meinshausen et al., 2011), and US is the region with large decrease in both NMVOC and NOx emissions. In US, the decrease of emissions concentrated in the eastern US, where the most population and industry are located. In the western US, the major cities are the main areas of emission reductions. Canada and Mexico shows decrease of NOx emissions in both scenarios; while in Mexico, NMVOC increase under RCP 8.5 and in Canada, NMVOC increases under RCP 4.5.

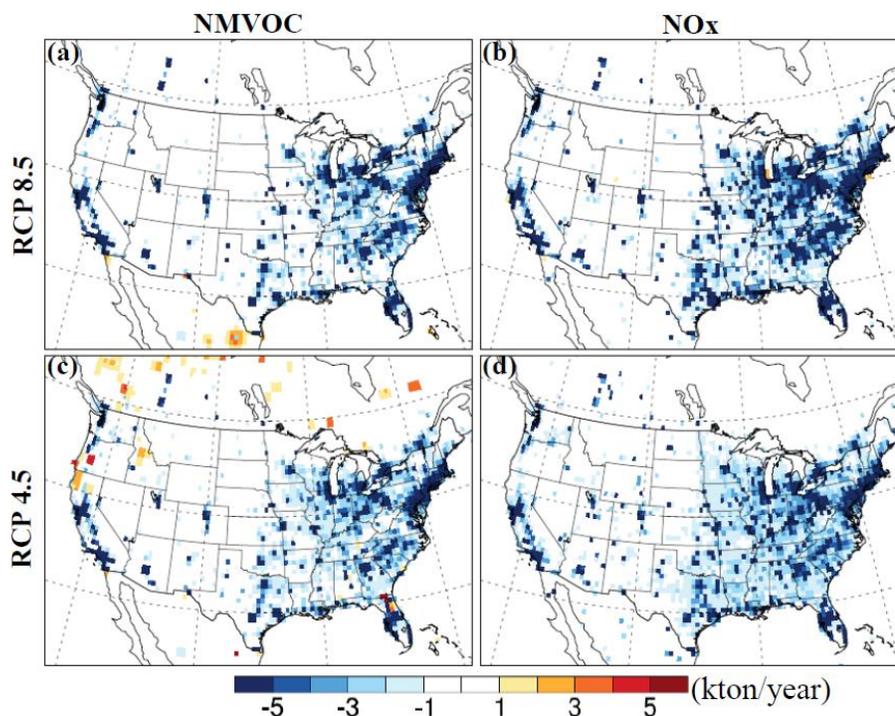


Fig. 3. Differences of NMVOCs and NO_x between 2005 and 2060 (2060-2005) under RCP 4.5 and RCP 8.5

5) The BVOC BEIS modelling system is mentioned in section 3 but some description of how it simulates BVOC emissions and its sensitivity on meteorology and CO₂ and appropriate references should be given. For example, is the CO₂ inhibition effect included? It would be useful to add the calculated values to Table 2 since they may (or may not) strongly influence ozone distributions. This would also enable further clarification of whether there may be differences in future simulated ozone between CMAQ and CAM-Chem as suggested (11324 line 5).

Response:

Biogenic Emissions Inventory System (BEIS) Modeling 3.14 was used to generate hourly biogenic emissions for each year at present (2001-2004) and future (2057-2059) climate. The calculation of biogenic emissions used empirical methods based on temperature at 2 meter and solar radiation (Guenther et al., 1993; Schwede et al., 2005). The biogenic emissions for the year of 2005 were obtained from US EPA* and the ratios of present and future biogenic emissions to the year of 2005, as well as the total NMVOC combining anthropogenic and biogenic emissions, were shown in Table 2.

* <http://www.epa.gov/ttnchie1/emch/>

The revised descriptions (Page 9, Line 254-269) are shown below:

As depicted in Table 2, most anthropogenic emissions in the US will decrease under both RCP 4.5 and RCP 8.5 scenarios. By the end of 2050s, CO decreases more than 70%; non-methane volatile organic compounds (NMVOC) and nitrogen oxides (NOx) decrease by almost 70% and 50% in RCP 8.5, and 40% and 60% in RCP 4.5. In contrast, ammonia (NH3) emissions increase in both scenarios, and methane (CH4) emissions increase by 60% in RCP 8.5. The biogenic NMVOC in US is 31.739 Tg in 2005, which is 72% higher than anthropogenic NMVOC (18.421 Tg). Under RCP scenarios, anthropogenic emissions are projected to decrease, while biogenic emissions are projected increase due to increased temperature. The combined effect leads to about only 10% reduction of total NMVOC by the end of 2050s. The biogenic NO emissions (not shown here) are relatively small, accounting for 6% compared to that from anthropogenic emission in the year of 2005. The future change of biogenic NO emissions are small as well due to less sensitivity to temperature compared to VOC. Please note as the global chemistry CAM-Chem runs held the biogenic emissions constant between 2000 and 2050s, and the large effect of biogenic NMVOC emissions could cause ozone difference between CAM-Chem and CMAQ.

Table 2. Projection factor for anthropogenic and biogenic emissions in US

	Present climate				2005(Tg)	RCP 4.5			RCP 8.5		
	2001	2002	2003	2004		2057	2058	2059	2057	2058	2059
CO	1.142	1.194	1.129	1.065	93.030	0.272	0.268	0.264	0.246	0.243	0.240
NOx	1.139	1.117	1.078	1.039	18.914	0.342	0.338	0.334	0.493	0.487	0.482
PM ₁₀	1.121	1.008	1.006	1.003	21.149	0.552	0.552	0.551	0.542	0.540	0.538
PM _{2.5}	1.282	1.022	1.015	1.007	5.456	0.761	0.754	0.747	0.422	0.417	0.413
SO2	1.092	1.012	1.008	1.004	14.594	0.169	0.166	0.163	0.148	0.137	0.126
NMVOC	0.929	1.149	1.112	1.074	18.421	0.632	0.630	0.628	0.314	0.310	0.306
BG-VOC*	0.913	0.971	1.008	0.993	31.739	1.111	1.098	1.173	1.266	1.212	1.275
T-VOC**	0.919	1.036	1.046	1.023	50.160	0.935	0.926	0.973	0.916	0.881	0.919
NH3	0.904	1.012	1.008	1.004	4.085	1.254	1.253	1.252	1.536	1.544	1.551
CH4	1.202	1.187	1.172	1.156	32.180	0.893	0.888	0.883	1.612	1.626	1.640
BC	1.007	1.005	1.004	1.002	0.394	0.723	0.716	0.709	0.264	0.262	0.260
OC	1.145	1.109	1.073	1.036	1.141	1.060	1.051	1.042	0.609	0.606	0.604

* BG-VOC indicates biogenic VOC emissions.

**T-VOC indicates the summation of anthropogenic NMVOC and biogenic VOC.

6) The whole section on statistical evaluations starts with the apriori assumption that the regional model will compare better to observations. If this is the premise, this section could benefit greatly by showing this by adding values from CAM-Chem to Table 3 or at least adding similar maps of ozone changes from CAM-Chem to figure 5 (or adding these to figure 4). The text describing Table 3 results could benefit from clearer writing and a description of the "space and time pairs" (e.g. numbers of space-time pairs, map showing sites used, temporal resolution). Furthermore, there are a number of speculative comments and it is unclear whether climate or climate-chemistry studies are being discussed. The evaluation metrics discussed refer to ozone. The text discusses that climate studies do not use these same statistical methods. Climate model evaluation studies use many sophisticated statistical techniques e.g. Taylor diagrams and the fact that they do not use those statistical metrics designed for ozone by the EPA is not a flaw per se. I would like to see a more succinct and less speculative write-up of this section pertaining to regional chemistry model evaluation. In addition: a) are all four statistical quantities needed since the NMB and MNB and similarly the NME and MNE are simply related by $1/N$, b) the concept of cut-off values need to be explained more clearly.

Response:

We added the observational sites to Fig. 1 (shown below), and there is a total of 1200 sites for O_3 , 450 sites for NO_2 and 450 sites for CO. The temporal resolution is hourly from the observational data and regional model CMAQ outputs, and this has been added in the revised manuscript.

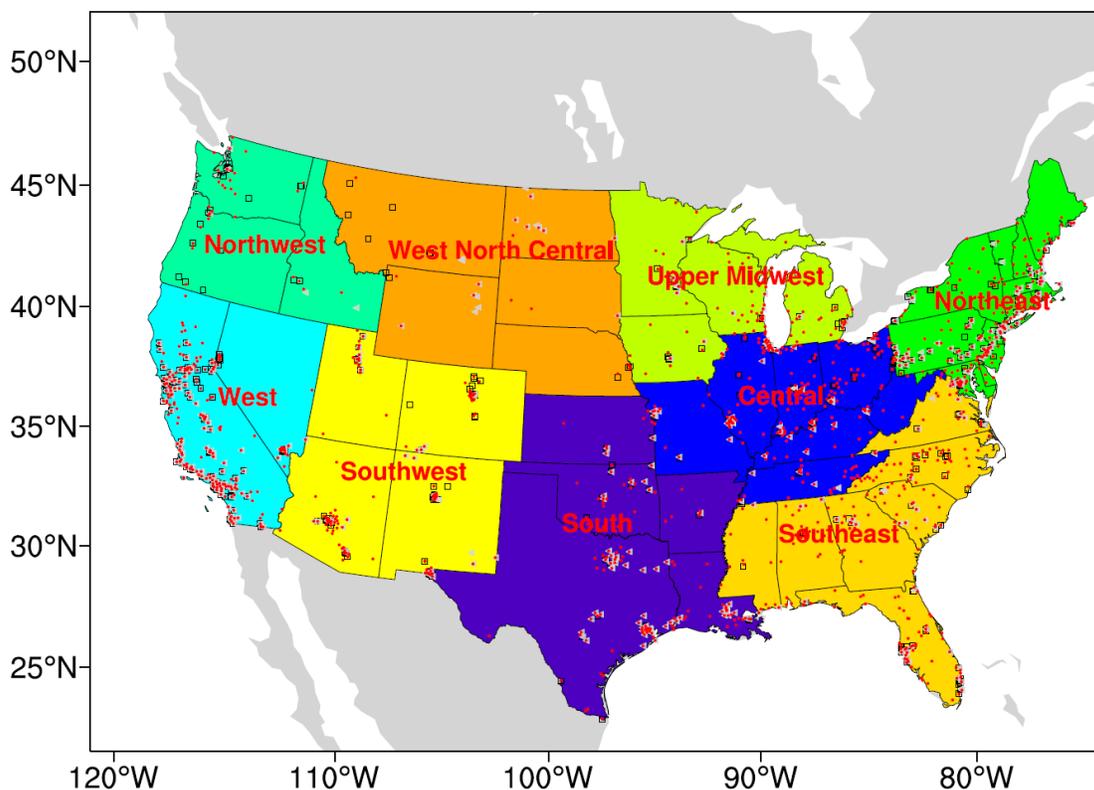


Fig. 1. 12 km by 12 km simulation domain with nine climate regions in US. The red points (~1200), the gray triangles (~450) and black squares (~450) represent the observational sites of O₃, NO₂ and CO, respectively, obtained from Air Quality System (AQS, <http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsddata.htm>).

As the reviewer suggested, we also evaluated the ozone changes under RCP scenarios from CAM-Chem (Fig. S1 a-h) outputs, and they show consistent patterns with CMAQ (Fig. 5 a-h), shown below. We found the magnitude differences between CAM-Chem and CMAQ, and this could be partly resulting from the emission differences in particular the biogenic emission differences explained in the last response. We did find the titration effect from CAM-Chem outputs as well as the reviewer pointed out in the next comments. This has been revised in the updated manuscript.

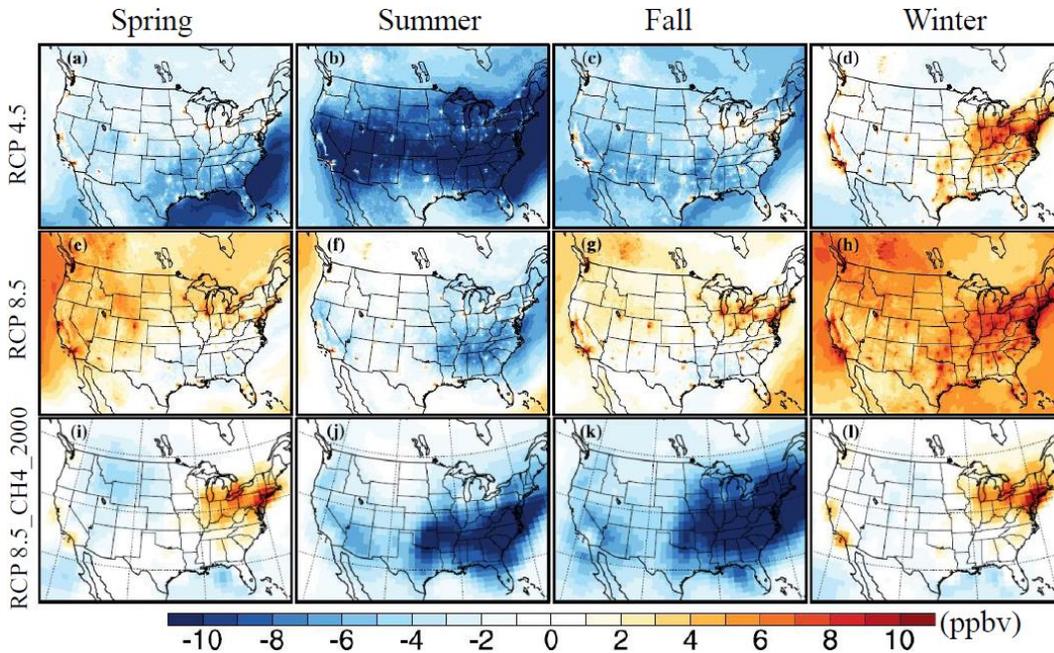


Fig. 5. Seasonal mean surface ozone changes from CMAQ outputs under future climate (2057-2059 minus 2001-2004) for RCP 4.5 (a-d), RCP 8.5(e-h), and the bottom panel (i-l) shows ozone changes by the end of 2050s without methane increases in RCP 8.5 (ozone in 2050s with 2000s methane concentrations – ozone in 2000s).

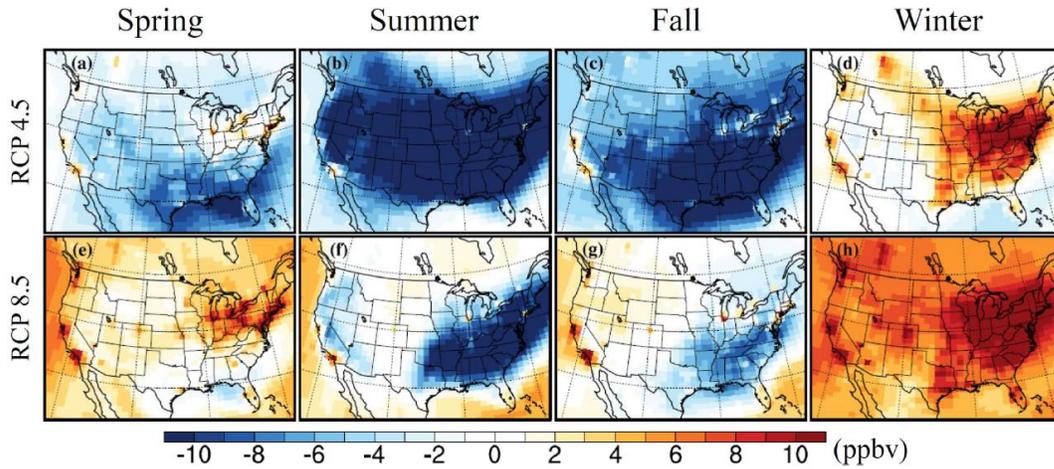


Fig. S1. Seasonal mean ozone changes from CAM-Chem outputs under future climate (2057-2059 minus 2001-2004) for RCP 4.5 (a-d), RCP 8.5(e-h), RCP 8.5 with present (2001-2004) boundary conditions (i-l)

The metrics of the NMB and MNB are similar as the NME and MNE. The reason we compared all these four metrics is: 1) these metrics are suggested by US EPA, and we want to look at the performance in terms of all these metrics; 2) the performance of these four metrics could be a reference to future studies, and some researcher may only use NMB/NME or MNB/MNE, and

they can compare with our results no matter which one they use. Thus, we include all these metrics in the evaluation.

As the reviewer advised, we added more explanations about the concept of cut-off values. The implementation of cut off values indicates that sites with ozone concentrations smaller than the cut off values were discarded. Below Table 2, we also added more explanations: The cutoff value of 40 ppbv means the observational sites with hourly ozone concentrations less than 40 ppbv were discarded in the evaluation.

7) The paper highlights STE enhancement of surface ozone in the 2050s climate, but are the high altitude changes in STE relevant for surface air quality? Fig 7 shows some possible evidence of this. This figure should be moved to section 5 where the other CAM-Chem results are discussed. Given the model set-up can change in STE in CAM-Chem can feed through to CMAQ? The CAM-Chem boundary conditions would need to capture the effect of increased stratospheric intrusions (Fig 7) that may occur far away from the domain boundary. It may well be that it is the higher methane concentrations that are solely responsible for the higher surface ozone in RCP 8.5. As such a strong connection is made between STE increases and seasonal and MDA8 ozone changes between present-day and future in figures 5 and 6, some inferences from the literature that discuss STE influences on surface ozone would be greatly beneficial. As discussed above, the more relevant figure for comparison to figure 5 is a seasonal map of lowest model layer changes in ozone from CAM-Chem. Indeed, it would be most interesting to see if the titration effect is seen in CAM-Chem. Collette et al. (2012, ACP) suggests that global models may be able to simulate such effects.

Response:

Thanks for the reviewer's comments. We removed Fig. 7 considering that the PV can not completely explain the STE. We deleted the discussions about STE. One of the primary reasons is the ozone increase in western US mainly occurs in RCP 8.5 not RCP 4.5. Since the stratosphere ozone increase in both RCP 4.5 and RCP 8.5, if the STE plays significant roles, we would also see some effect in western US in RCP 4.5 as well. The major differences between RCP 4.5 and RCP 8.5 are the methane emissions, and we further evaluated the sensitivity study and found significant contributions from methane concentrations, shown in Fig. 5 below.

The revised descriptions (Page 13, Line 387-395) are shown below:

The simulations were conducted using CAM-Chem for the period of 2050s by maintaining the methane concentrations at 2000 level. Fig. 5 (i-l) shows ozone changes in 2050s compared to

present climate under RCP 8.5 without methane increase. Compared to Fig. 5(e-h), in spring and winter, the ozone increases areas and magnitudes were dramatically reduced, leaving small areas of ozone increase resulting from titration effect. In summer and fall, much larger decrease (comparing Fig. 5i, k and f, g) occurs if methane concentrations maintain at 2000 level. The sensitivity study clearly addressed the significant role of methane concentrations play on ozone concentrations, and the impact could be as large as 4-8 ppbv.

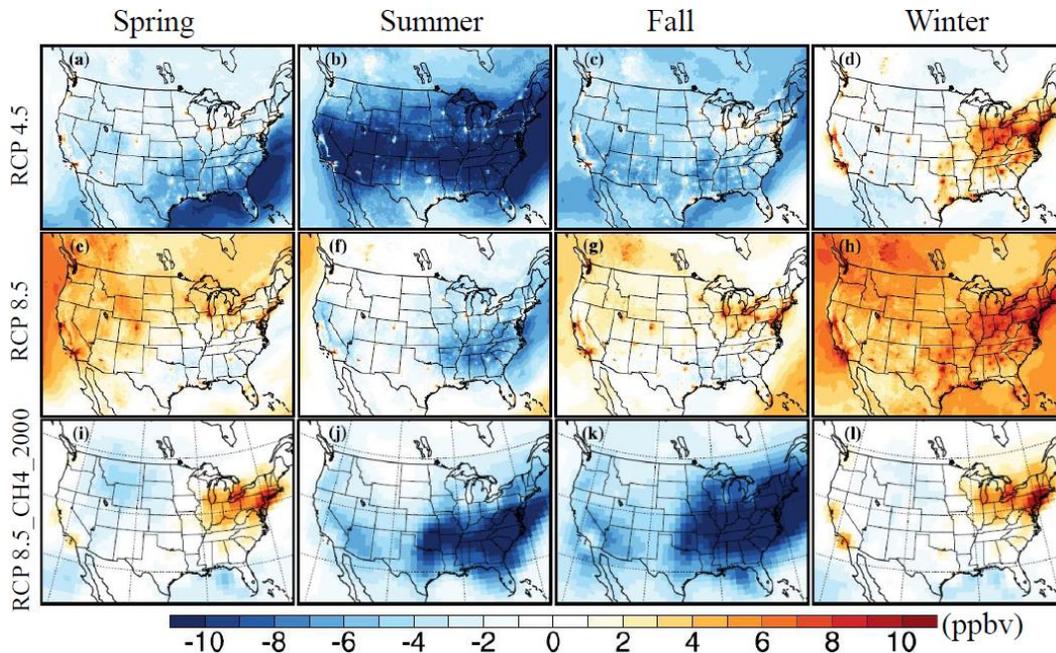


Fig. 5. Seasonal mean surface ozone changes from CMAQ outputs under future climate (2057-2059 minus 2001-2004) for RCP 4.5 (a-d), RCP 8.5(e-h), and the bottom panel (i-l) shows ozone changes by the end of 2050s without methane increases in RCP 8.5 (ozone in 2050s with 2000s methane concentrations – ozone in 2000s).

We did see the titration effect around big cities in US, shown in Fig. S1 (response to question 5), consistent with what was found by Collette et al. (2012, ACP). This has been added in the revised manuscript (Page 13, Line 380-382).

8) Regarding Figure 4 this figure should at least use the same periods as used in Figure 5. As it stands, spring and winter features in the lower troposphere in Fig 4. appear similar. The scale should be improved so that values of ~ 1 ppbv as discussed in the text can be clearly seen. There is a paragraph of text describing the results from a sensitivity experiment that are not shown. Either this figure should be included, or the relevant text condensed or omitted to achieve a more focused discussion.

Response:

Thanks for your suggestion. We changed Figure 4 to the same period as Figure 5 and also only show North hemisphere since this is the major focus of this study. The descriptions and the legend have been revised. The discussion of the sensitivity study has been moved to the end of section 5.1 (Fig. 5 and its description as shown by responding question 7)

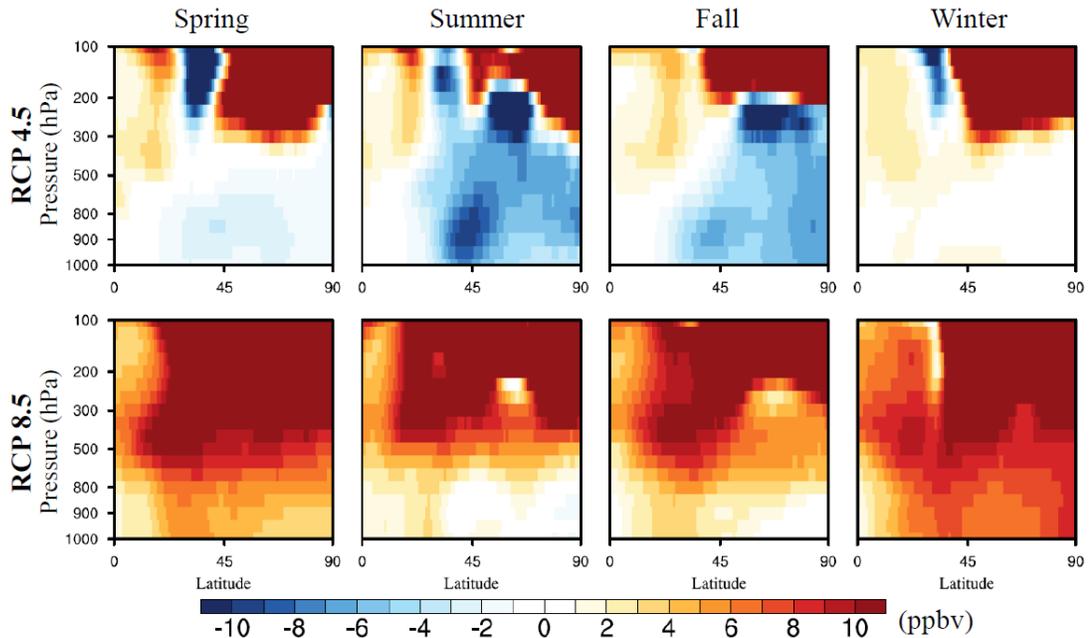


Fig. 4. Zonal mean vertical ozone changes from CAM-Chem under future climate (2057-2059 minus 2001-2004) for RCP 4.5 (top panel) and RCP 8.5 (bottom panel).

9) Some further explanation is needed for the methods of determining MDA8 during heatwave and non-heatwave periods. How do the sample sizes vary between these two categories? It would seem likely that there are far more non-heatwave days than heat wave days in the period June-October. It would also be useful to have some text or additional panels that show these quantities and ranges for the present-day period. The explanation for the lack of distinction between MDA8 during heatwave and non heatwave events in three of the nine regions under RCP 4.5 is based on the values of annual heatwave events being less than "3" in these regions. Yet three of the remaining regions also have heat wave events less than "3". A similar argument for RCP 8.5 is less clear. This is why sample size may be important. A statistical test that enables the authors to comment on whether the shifts between heatwave and non heatwave events are significant or not would be most beneficial. Finally, it would ease interpretation to have the values for 60 and 75 ppbv (middle and top rows of each panel) in Fig 9 given as ppbv (as in the bottom row) rather than percentages.

Response:

We really appreciate the reviewer pointed out the importance of the sample size. We did careful comparison among all the nine regions regarding the sample size. The reviewer is correct, and the sample size of heat wave days is mostly much smaller than non-heat wave days, and the percentage of heat wave days to non-heat wave days ranges from 5% to 17% under RCP 4.5, and 21% to 35%. Thus, we redraw the distribution by comparing entire period and non-heat wave period. In this case, the sample sizes between them are similar and the impact of heat waves was included in the entire period. Since the sample size is similar, we kept the percentage differences of MDA8 ozone greater than 75 or 60. The other reason is the percentage exceedance is more interesting to know considering the non-attainment (exceedance of 75 ppbv) standard from US EPA.

The revised descriptions (Page 16, Line 475-502) are shown below:

The heat waves discussed above most occur from June to October; we therefore investigated the impact of heat waves during these five months. The sample size of heat wave days is mostly much smaller than non-heat wave days, and the percentage of heat wave days to non-heat wave days ranges from 5% to 17% under RCP 4.5, and 21% to 35%. The sample size between the entire period (including heat wave and non-heat wave period) and non-heat wave period is similar, and the MDA8 distributions during entire period and non-heat wave period were shown in Fig. 8. All model grids are used for each climate region in the analysis.

Under RCP 8.5, the mean MDA8 shows increases across US except Southeast, during the entire period compared with non-heat wave period, and the increase are all statistically significant, ranging from 0.3 ppbv to 2.0 ppbv. The ozone exceedance of 60 ppbv and 75 ppbv during the non-heat wave period is on average 1-8% and 0-4% lower than the entire period respectively. Under RCP 8.5, the TMX is statistically higher during the entire period than non-heat wave period, ranging from 0.8 to 2.0 °C. One of the major reasons Southeast does not show statistically significant increase in MDA8 is its position adjacent to the ocean and its small diurnal temperature variations (Fig. S2 shown below). Under RCP 4.5, statistically significant MDA8 increase occurs in five regions, however, the increase magnitudes (maximum of 0.7 ppbv) are much smaller than RCP 8.5. The 95% confidence interval of the MDA8 differences between entire period and non-heat wave period was also shown in Fig. 8. The upper 95% limit indicates 0.4 ppbv to 1.5 ppbv increase under RCP 4.5 and 1.2 ppbv to 3.2 ppbv increase under RCP 8.5 was resulted from heat waves without including Southeast (increase of 0.6 ppbv). Even though the

temperature increase in RCP 4.5 due to heat waves is statistically significant, the ozone precursors including NMVOC and NO_x decreased dramatically and the methane emissions decrease by ~10% (Table 2) as well. As is explained in section 5.2, methane is the major contributor in ozone increase in RCP 8.5, and without enough ozone precursor emissions in RCP 4.5, the heat waves may not play as significant role as it does in RCP 8.5.

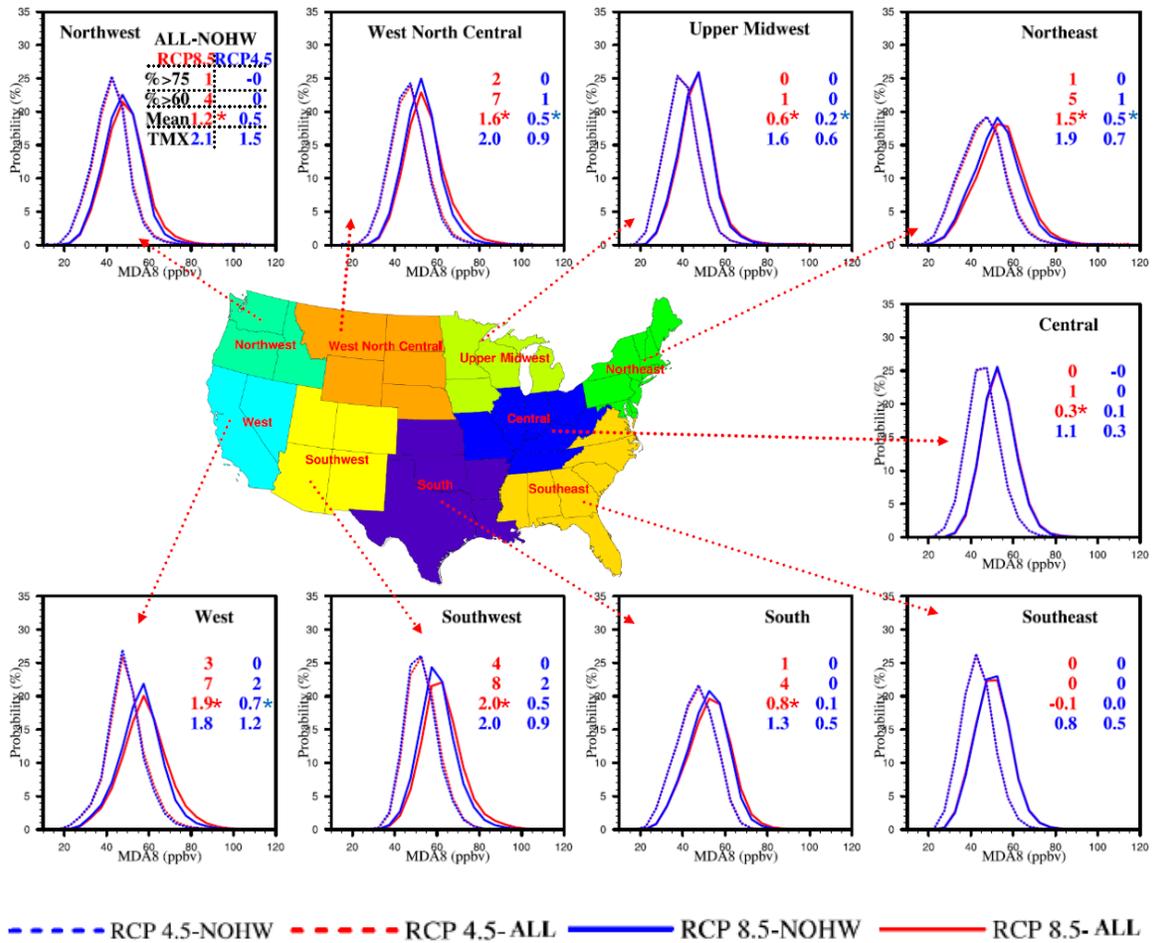


Fig. 8. Distributions of MDA8 during the entire period (referred to as ALL) and non-heat wave period (referred to as NOHW) for RCP 4.5 and RCP 8.5 from June to October. There are two columns of numbers, and they represent percentage of MDA8 ozone exceeding 70 ppbv (top row) and 60 ppbv (second row), mean MDA8 ozone (third row) and mean daily maximum temperature (TMX) for both scenarios. Statistical significance was tested and marked with star to indicate statistical significant. All TMX mean differences are statistically significant.

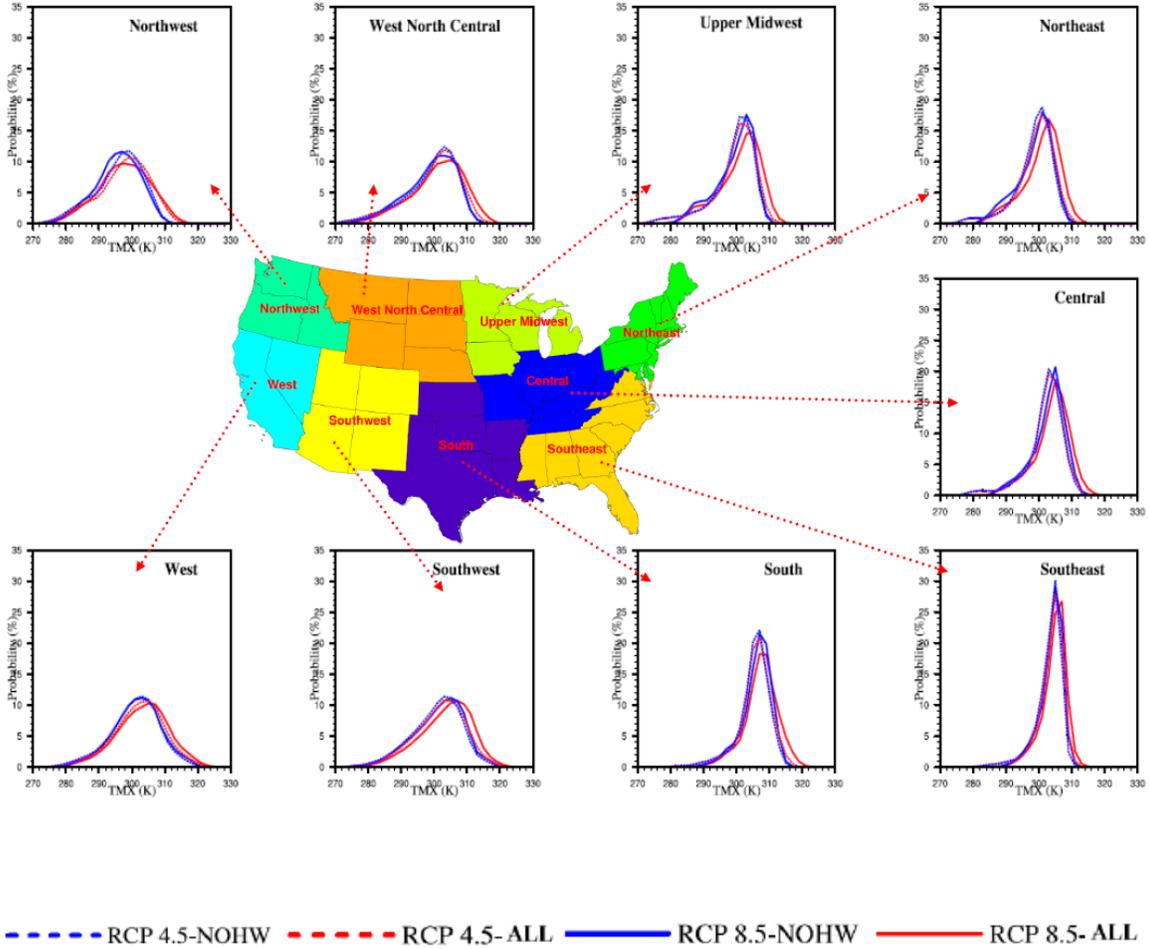


Fig. S2. Distributions of daily maximum temperature (TMX) during the entire period and non-heat wave period for RCP 4.5 and RCP 8.5 from June to October.

Specific comments:

The abstract could be clearer in distinguishing between global results from CAM-Chem and regional ozone air quality from CMAQ.

Response:

We have revised the abstract (Page 1, Line 16-40). to make it clearer.

Dynamical downscaling was applied in this study to link the global climate-chemistry model Community Atmosphere Model (CAM-Chem) with the regional models: Weather Research and Forecasting (WRF) Model and Community Multi-scale Air Quality (CMAQ). Two Representative

Concentration Pathway (RCP) scenarios (RCP 4.5 and RCP 8.5) were used to evaluate the climate impact on ozone concentrations in 2050s.

From the CAM-Chem global simulation results, ozone concentrations in the lower-mid troposphere (surface to ~300 hPa), from mid- to high latitudes in the Northern Hemisphere, decreases by the end of 2050s (2057-2059) in RCP 4.5 compared to present (2001-2004), with the largest decrease of 4-10 ppbv occurring in the summer and the fall; and increase as high as 10 ppbv in RCP 8.5 resulting from the increased methane emissions.

From the regional model CMAQ simulation results, under the RCP 4.5 scenario (2057-2059), in the summer when photochemical reactions are the most active, the large ozone precursor emissions reduction leads to the greatest decrease of downscaled surface ozone concentrations compared to present (2001-2004), ranging from 6 to 10 ppbv. However, a few major cities show ozone increases of 3 to 7 ppbv due to weakened NO titration. Under the RCP 8.5 scenario, in winter, downscaled ozone concentrations increase across nearly the entire continental US in winter, ranging from 3 to 10 ppbv due to increased methane emissions. More intense heat waves are projected to occur by the end of 2050s in RCP 8.5, leading to 0.3 ppbv to 2.0 ppbv increase (statistically significant except Southeast) of the mean maximum daily 8-hour daily average (MDA8) ozone in nine climate regions in US; Moreover, the upper 95% limit of MDA8 increase reaches 0.4 ppbv to 1.5 ppbv in RCP 4.5 and 0.6 ppbv to 3.2 ppbv in RCP 8.5. The magnitude differences of increase between RCP 4.5 and 8.5 also reflect the increase of methane emissions may favor or strengthen the effect of heat waves.

11316, Line 8: the wording "trend" is inappropriate. These are differences between two 10-year periods. Also 11328, line 22.

Response:

The word "trend" has been deleted.

11317, line 22: the text on "impacts of climate : : : on air quality with spatial resolutions of .." reads awkwardly . It would be simpler to state that global chemistry models have resolutions of 1-2 degrees or more.

Response:

This has been changed in the updated manuscript (Page 2, Line 58-62), also shown below.

In order to further evaluate the relationships between atmospheric chemistry and climate change under RCP scenarios, and to support the IPCC AR5, the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP) has been established and global chemistry models have resolutions of 1-2 degrees or more.

11317, line 26: global studies of?

Response:

“global studies” has been changed to “global climate/chemistry studies” (Page 3, Line 66)

11318, line 15: explain "five-summer"

Response:

This means five year summer time. We changed "five-summer" to five-year summer (Page 3, Line 82)

11318, line 18 The linkage between the two results (climate change only, climate change + emission reductions) found by Lam et al. (2011) is rather unclear.

Response:

This sentence has been re-written (Page 3, Line 84-88) as follows:

In the eastern US, Lam et al. (2011) found 2 to 5 ppbv increase of MDA8 in 2050s compared to 2000s, with climate change under A1B scenario while maintaining emissions at 2000s level ; a ~5 ppbv decrease under A1B scenario from the combined effect of climate change and emission reductions was found with spatial resolutions of 36/12 km.

11319, line 17: "under the same climate scenarios" is unnecessary.

Response:

"under the same climate scenarios" has been deleted.

11319, lines 26- 11320 lines1- 7, 17, 11325 line 7: "the" should be inserted before model names and before "model top".

Response:

“the ” has been inserted in all of these places.

11319, line 8, representation of ? in the atmosphere.

Response:

representation of atmospheric chemistry. This has been revised in the manuscript (Page 5, Line 139).

11321, line 20, Re-phrase "comparison with observations of CAM-Chem".

Response:

This has been changed to "The evaluation of CAM-Chem" (Page 6, Line 180)

11321, line 25 add "ozone" before "air quality".

Response:

This has been added.

11322 line 16: Clarify what "driven by the default profile initial and boundary conditions" means.

Response:

The default CMAQ initial and boundary conditions are relatively clean air conditions (<http://www.epa.gov/AMD/Research/CMAQ/ch13.pdf>). As suggested by Carlton et al. (2010), we used the simulations driven by the default initial and boundary conditions to achieve the ratios among the SOA species. The manuscript has been revised (Page 7, Line 209-212).

Carlton, A. G., Bhave, P. V., Napelenok, S. L., Edney, E. O., Sarwar, G., Pinder, R. W., Pouliot, G. A., and Houyoux, M.: Model Representation of Secondary Organic Aerosol in CMAQv4.7, *Environ. Sci. Technol.*, 44, 8553-8560, 10.1021/es100636q, 2010.

11323: line 1: change "for example" to "as an example".

Response:

This has been changed (Page 8, Line 222).

11323: line 7: the 1st sentence of this section is unclear, different patterns compared to?

Response:

The figure has been changed and the descriptions have been revised (Page 8, Line 230-231) as well.

11323: line 14: India is already a major emission source region

Response:

As the reviewer suggested, we now only focus on the emission discussions of US. The discussion of India emissions has been removed.

11324: line 15: explain what is meant by "retrospective studies".

Response:

"retrospective studies" means meteorological simulations were driven by reanalysis data. This has been addressed in the updated manuscript (Page 10, Line 273-275).

11324, line 16, "However: : : climate studies.." does not seem relevant.

Response:

This sentence has been deleted.

11324, line 19: Evaluation is usually performed based on the quantity or metric of interest. To state that global models compare zonal and monthly mean values due to their coarse resolution is overly speculative.

Response:

This sentence has been removed and we focus on the regional model evaluation.

11325, line 22 re-phrase "at present climate condition" and explain what is meant by "meet the criteria".

Response:

We rephrased the sentence (Page 11, Line 306-307):

Considering all the AQS sites from 2001-2004, all statistical metrics for O₃ with 40 ppbv cut off meet the benchmark from US EPA (2007).

Basically, the criteria mean the benchmark that MFB is 15% and MFE is 35%.

11327, line 6 clarify "a stronger chemical reaction".

Response:

We rephrased the sentence (Page 1, Line 344-345):

This is the result of a higher reduced ozone production rate resulting from large reduction in anthropogenic emission in summer and fall than the other two seasons.

11328: re-phrase "reduced photochemical reactions" as it is the rate that is sensitive to temperature.

Response:

This has been changed to "reduced photochemical reaction rates" (Page 13, Line 365-366)

11329: line 14: is the higher ozone near the surface in winter in Figure 4 really due to effects at the stratosphere? Please add any appropriate references. Also explain the role of intercontinental transport more clearly referring to Figure 3.

Response:

We have studied the impact of methane as the reviewer suggested, and found the methane concentrations are the major driver. This has been explained when we respond the reviewer's comment 7.

11332, Are the temperatures those simulated by WRF? Explain how future climate as simulated by CESM affects WRF daily temperatures. Comment on whether the heatwave results for RCP 8.5 are the same as those reported in Gao et al. 2012.

Response:

Right, the temperatures used here are simulated by WRF. The boundary conditions from CESM were used to drive WRF, and temperature is one of the variables used as boundary conditions. Thus, the temperature change in CESM was reflected by WRF through boundary conditions. The discussions of heat waves used the same methods used in Gao et al. 2012. In Gao et al., we mainly focus on eastern US, while in this study, we focus on the entire US. The data used for determination of heat waves are from the same WRF simulations.

11333- 11334 line 5: The conclusions on model evaluation are rather vague and long.

Response: The conclusions have been revised (Page 18, Line 506-538) the discussions of model evaluations have been removed.

11334, line 15, more details of?

Response:

more details of ozone change. This has been updated in the revised manuscript (Page 17, Line 515).

11334, line 18 should be "titration".

Response:

This has been changed (Page 17, Line 518).

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11335, line 2: Fig 8 shows the maximum regional heat wave duration is 7.6 days rather than 10 days.

Response:

The conclusion has been changed (Page 18, Line 506-538).

Table 2: clarify "projection factor". Also methane emissions are given. Clarify whether methane emission or concentrations were used in the CAM-Chem or CMAQ simulations.

Response:

We changed the title of Table 2 (Page 29, Line 919-923) to make it clear. Table 2. Anthropogenic and biogenic emissions compared to base year (2005) emissions in US

A footnote was also added below Table 2 to explain ***CH4 indicates methane emissions.

Table 3: explain that the benchmark is only for two of the metrics listed.

Response:

This has been explained under Table 3 (Page 30, Line 943).

Figure 5 caption: should mention "surface".

Response:

This has been added (Page 35, Line 1034).

Figure 8 caption: further clarity is needed here, explain that these heatwave metrics are based on temperatures simulated by WRF 3.2.1.

Response:

This has been revised (Page 37, Line 1061-1062), shown below:

The heat wave duration and frequency derived from the daily maximum temperature simulated by WRF 3.2.1.