The paper uses a regional modeling system to simulate ozone in the vicinity of Phoenix and perform a series of sensitivity studies to determine the relative contributions of local and distance sources on ozone in Phoenix. While the tools used are not novel and the model simulates processes that have been discussed previously in the literature(e.g., mountain-chimney effect), what is different about this paper is how the model has been used to simulate the regional scale transport from California to Phoenix at high-spatial resolution encompassing this region. In this way, the effects of the complex terrain in California on the winds and transport are represented in a realistic way. The paper definitely demonstrates the importance of distant sources on local air quality. Overall, the methods used are sound and the discussion on the results is well organized, but some additional discussion is needed to clarity important missing information.

The authors appreciate the reviewer's comment and suggestions. Following is point-by-point response.

General Comments:

Although I found the model performance for the surface stations credible, there is no evolution of the model aloft. The authors presents several figures on transport aloft, but their analysis relies totally on the model. Including some observations aloft would have strengthened the author's assertions regarding transport. At a minimum, the authors should include some sort of analysis of the performance of the wind and temperature aloft. I understand there may be no data available on ozone and the other chemical species aloft for the two case studies chosen. The authors should at least discuss the fact that many, many air quality campaigns have been sampled ozone and other trace gasses aloft. It is reasonable to expect that at least some of these cases may have been suitable to study transport to Phoenix. Perhaps some discussion at the end of the manuscript could be added to state what sort of data is needed to further refine the analysis and better quantify the relative role of local and distant emission sources on concentrations in Phoenix.

Thanks for the suggestion and comments.

The 850 hPa and 700 hPa wind and temperature discussion is added (Lines 236-243) in the revised version and a supportive Figure (Figure S1) is added also.

"The wind and temperature comparisons between WRF-Chem in Domain 1 and NARR data are examined. Generally, the simulations are consistent with NARR data in patterns and magnitudes for the two cases. More specifically, there were continuous, westerly winds between southern California and central Arizona for both NARR and simulations at 850 hPa. Figure S1 is the example of the comparison of wind and temperature at 850 hPa (bottom panel) and 700 hPa (top panel) for the average of July 16-19, 2005."

The relevant discussions for vertical distributions for trace gasses are added in the revised version(Lines 529-543):

"In past decades, there were a few field experiments conducted to measure the vertical distributions of meteorological fields and trace gasses in southern California (e.g., the southern California Air Quality Study in 1987 [Lawson, 1990]; the southern California Ozone Study in 1997[Groes and Fujita, 2003] and CALNEX-2010[www.esrl.noaa.gov/csd/calnex/]) as well as in Phoenix area (e.g., Phoenix Air Flow Experiment II in 1998 [Fast et al. 2000; Nunnermacker et al., 2004]). Some of the events during the experiments have been used to address ozone transport (e.g., Huang et al. 2013; Langford et al., 2010) from the southern California coast. No aloft measurements could be found for May 2010 that would be of help in the present model performance evaluation. In addition, satellite-retrieved data may also be used to demonstrate the vertical distributions and even distant transport (e.g., Huang et al., 2013), although these

data exhibit limitations for air quality studies such as coarse-resolution, accuracy, etc. (e.g., Bowman, 2013). To quantitatively examine the transport and vertical distribution from southern California coasts to Phoenix, field observations, especially measurements aloft, along the inland California desert region and within western Arizona are needed."

Another area that needs additions discussion is the general meteorological conditions during the two cases and whether they are common or not. I assume that both of these periods are mostly sunny conditions? If this was for some other location, clouds would likely affect photochemistry at least somewhere in the domain. It is possible that there are mostly clear skies in the cases. Normally some sort of evaluation of cloudiness is needed as well in the simulation because of its affect on photochemistry.

Thanks for pointing this out. This paragraph is revised as (Lines 209-216):

"For both events, the synoptic weather in southern California and south-central Arizona was nearly calm, clear, and sunny with light westerly winds within the lower troposphere for the time periods discussed in this manuscript, based on NARR 3-hourly data. In addition, these two events represent pre-monsoon season and monsoon season, respectively, two typical climate circulations (Adams and Cowrie, 1997) during the ozone season.

The model (WRF-Chem) is initialized four days prior to each episode, with the data of the first 24-hours being discarded. In addition, analysis nudging is applied for the meteorological fields (U, V, T, GPH, and Q) above the PBL in the outer most domain for the first 24 hours."

Specific Comments:

Page 8362, Line 5: Change "Control" to "control"

Changed.

Page 8362, Line 7: Add "US" to Environmental Protection Agency.

Added.

Page 8366, Line 9: The authors should include which version of WRF-Chem is being used.

Added in the text. WRF-Chem version 3.5.1 is used.

Page 8367: Lines 9-11: I do not think acronyms are needed for these areas are needed since they are not used that often and there is already plenty of acronyms in the text.

The acronyms are removed from the text.

Page 8369: Line 10: which observations are being referred to? Are these all the stations shown in Figure 1b? Please be specific.

Added in the text: Circles in Figure 1b.

Page 8370: Lines 3-5: The authors do not mentioned whether data assimilation is used in the present simulations or not. So, I have to assume that it is not and that NARR influences the model simulation only

through initial and boundary conditions. The domain is rather large, so the model could drift over a four-day simulation period. Given that the focus of this paper is transport from California to Phoenix and much of that transport is aloft, it would be useful to have some sort of evaluation of the model performance aloft.

Thanks for the suggestion and comments.

The following paragraphs are added in Lines 214-216, and Lines 236-243, respectively.

"The model (WRF-Chem) is initialized four days prior to each episode with the data of the first 24hours discarded. In addition, analysis nudging is applied for the meteorological fields (U, V, T, GPH, and Q) above the PBL in the outer most domain for the first 24 hours."

"The wind and temperature comparisons between WRF-Chem in Domain 1 and NARR data are also examined. The simulations are consistent with NARR data in patterns and magnitudes for the two cases, in general. More specifically, there were continuous, westerly winds between southern California and central Arizona for both NARR and simulations at 850 hPa. Figure S1 is the example of the comparisons of wind and temperature at 850 hPa (bottom panel) and 700 hPa (top panel) for the average of July 16-19, 2005."

Page 8370: Line 6: As with Table 1, I would find 2 figures more useful. One showing the results for southern California and the other for those around Phoenix. The point of this paper is showing contributions of pollutants from California transported to Arizona, so knowing the model performance in the sources region is critical.

Table 1 is revised based on two regions separately.

Table 1: Statistical results of hourly surface [O_3] from model simulations at 1 km and 4 km resolutions in Southern CA and Central AZ

	11-14, May 2012				16-19, July 2005			
	CA	CA	AZ	AZ	CA	CA	AZ	AZ
	1km	4km	1km	4km	1km	4km	1km	4km
Mean Bias (ppb)	-1.9	-3.4	0.6	-0.4	-2.0	-4.0	-4.8	-4.7
Normalized Mean Bias (NMB)	-7.9	-13.5	2.5	-1.7	-8.6	-16.3	-18.5	-18.4
Normalized Mean Error (%)	16.3	25.0	15.4	16.8	24.2	34.1	24.1	25.6
Mean Normalized Bias (%)	-6.7	-10.7	3.2	-1.2	-3.5	-9.7	-16.4	-18.5
Mean Normalized Gross Error (%)	16.7	24.9	15.9	17.3	23.8	34.0	24.5	26.2
Correlation coefficient	0.75	0.54	0.76	0.65	0.74	0.4	0.75	0.61
Root Mean Square Error (ppb)	16.1	19.9	15.7	15.5	22.9	30.1	15.8	17.2

A figure for ozone concentration variation in south California and greater Phoenix is added as figure S3 in supportive materials. And the following paragraph is added in the revised version (Lines 268-278):

"Figure S3 shows [O_3] time series separately for southern California and greater Phoenix, corresponding statistics are shown in Table 1. In checking Figure 3, and Figures S2 and S3, although the NEI-2005 over-estimated CO and NOx emissions in 2012 in the south coast

airshed, California, causing [NOx] and [CO] to be over-estimated as well, the ozone simulations nonetheless appear to be quite acceptable. One explanation could be that this airshed is categorized as a VOC-limited ozone environment. Under this condition, ozone concentrations are restrained by VOC concentrations. In other words, reducing NOx fails to reduce ozone concentrations (e.g.,Taha et al., 1998) and the same is also found in Phoenix area(Fast et al., 2000, Lee and Fernando, 2013), which can partly explain why the modeled [O_3] matched the observations, even though the modeled [NOx] and [CO] are highly overestimated in the May case."

Page 8370, Line 16-22: I understand the authors are trying to note the NEI05 emissions for their May 2012 case will be problematic, I find the justification about the reductions used in other studies is pointless since they do not try to adjust the emissions anyway. Those studies may use different reductions but none of them are likely be "corrected" since the model is not a prefect representation of real conditions. What they are simply doing is adjusting the emissions to best fit the model to observation.

Line 16-22 are removed from the text. Instead, emission changes are discussed (Lines 254-260) and a figure (Figure S2) is added as supportive figure:

"Figure S2 shows the emissions between the South Coast Air Basin, California and Maricopa County, Arizona for 2005 and 2011 for Maricopa County and 2012 for South Coast airshed. Relative to 2005, anthropogenic emissions of CO, NOx, and VOC are reduced about 40-50% in 2012 in the south coast airshed, California. Therefore, the NEI 2005 over-estimates [CO] and [NOx]."
South Coast emission data are downloaded from
http://www.arb.ca.gov/app/emsinv/fcemssumcat2013.php.

Maricopa County emission data are downloaded from
http://maricopa.gov/aq/divisions/planning_analysis/emissions_inventory/Default.aspx

Page 8371, Line 2: The authors need to state how many stations are included in the analysis. Are these only for Phoenix or for a larger region? They should refer to Figure 1. Also, it would be useful to segregate the statistics for those around Phoenix and those in southern California.

The number of sites used has been added in the text. Table 1 and Figure S3 show the results of greater Phoenix and southern California, separately.

Page 8371, Line 14: Change "concentrations" to "ozone concentrations". The NOx and CO for the 2012 case are much higher than observed, however, So, despite errors, in precursor emissions, ozone still fails into the range of accepted EPA criteria?

Thanks for the comments and the following paragraph is added in revised version (Line 268-278).

"Figure S3 shows [O_3] time series separately for southern California and greater Phoenix, corresponding statistics are shown in Table 1. In checking Figure 3, and Figures S2 and S3, although the NEI-2005 over-estimated CO and NOx emissions in 2012 in the south coast

airshed, California, causing [NOx] and [CO] to be over-estimated as well, the ozone simulations nonetheless appear to be quite acceptable. One explanation could be that this airshed is categorized as a VOC-limited ozone environment. Under this condition, ozone concentrations are restrained by VOC concentrations. In other words, reducing NOx fails to reduce ozone concentrations (e.g.,Taha et al., 1998) and the same is also found in Phoenix area(Fast et al., 2000), which can partly explain why the modeled [O_3] matched the observations, even though the modeled [NOx] and [CO] are highly overestimated in the May case."

Page 8373, Lines 24-26: I am not convinced of this statement. This simulation includes ozone from the boundary condition that varies in time as well. So the authors have not separate out just the biogenic contribution. There is some diurnal variability seen in the time series that does suggest a biogenic effect, however.

These sentences are revised (Lines 374-379):

"(3) the DMA8 [O_3] from the BEO experiment are in excess of 30 ppbv, including the contributions of biogenic emissions and lateral boundary transport. Based on the diurnal variation shown in Figures 4 and 5, and Figures S4 and S5, [O_3] due to biogenic emissions could be 10-17 ppbv. In other words, the contribution of BEO emissions to Phoenix DMA8 [O_3] cannot be ignored despite the region's aridity and relative lack of dense forests. Note that all of these results are based on the US EPA 2005 National Emission Inventory."

Page 8375, Line 6: The authors mention the height of model level 5m and 17, but do not mention what the height is for level 13.

Level 13 is about 1100 m a. g. l. and added in text.

Page 8379, Line 16: Change "EPA" to "the US EPA"

This sentence is removed from the revision version.

Figure 10: include the date of the plots.

The date is added in the caption.

Dereferences:

Adams, D., and Cowrie, A.: The North American monsoon, BAMS, 78(10), 2198-2213,1997.

Bowman, K.: Toward the next generation of air quality monitoring: Ozone, Atmos. Environ., 80, 571-583, 2013.

Cores B., and Fujita, E.: Overview of the 1997 southern California ozone study (SCOS97-NARSTO), Atmos. Environ.,37,3-26.doi:10.1016/S1352-2310(03)00379-0., 2003.

Fast J., Doran J., and Shaw W.: The evolution of the boundary layer and its effect on air chemistry in the Phoenix area, J. Geophys. Res., 105(D18), 22833-22848, 2000.

Huang, M., Bowman, K., Carmichael, G., Pierce, B., Worden, H., Lou, M., Cooper, O., Pollack, I. Ryerson, T., and Brown, S.: Impact of Southern California anthropogenic emissions on ozone pollution in the mountain states: Model analysis and observational evidence from space, J. Geophys. Res-Atmos., 118, 12784-12803, 2013.

Langford A., Senff C., Alvarez R., Banta R., and Hardesty R.: Long-range transport of ozone from the Los Angeles Bsin: A case study, *Geophys. Res. Lett*, **37**, L06807,doi:10.1029/2010GL042507, 2010.

Lawson D.: The southern California air quality study, J. Air Waste Manage. Assoc., 40,156-165, 1990.

Nunnermacker L., Weinstein-Lloyd J., Kleinman L., Daum P., Lee Y., Springston S., Klotz P., Newman L., Neuroth G., and Hyde P.: Ground-based and aircraft measurements of trace gases in Phoenix, Arizona (1998), Atmos. Environ., 38, 4941-4956, 2004.

Lee S., and Fernando H.: Dispersion of an urban photochemical plume in Phoenix metropolitan area, *Atmos. Environ*., **80,** 152-160, 2013.

Taha H., Konopacki S, and Akbari H.: Impacts of lowered urban air temperature on precursor emission and ozone air quality. J. Air Waste Manage. Assoc., 48, 860-865, 1998.

Response to Reviewer 2

The authors present the contribution to ground level ozone in Phoenix from local sources in Arizona and sources in southern California. The assessment is done using the WRF-Chem coupled prognostic meteorology and chemistry modeling system. Emissions are based on 2005 National Emission Inventory. The contribution assessment is done using brute emission changes (zero out) and comparing the results to original baseline (control) simulation. All contributions are estimated using the 1.33 km domain covering southern California and Arizona to better capture air flow through important orographic features between the Los Angeles area and Phoenix area. Model application at such a fine scale to resolve important terrain features between 2 large cities to capture regional transport is useful and generally well presented in the figures. The illustration if air flow through valleys in the vertical and horizontal dimensions is particularly notable. Overall this is a good analysis characterizing local and regional contribution to Phoenix.

The authors appreciate the reviewer's comments, suggestions, and discussions. Following is a point-by-point responses.

The model results at 1.33-km suggest that WRF is adequately capturing important terrain features that channel ozone from southern California to Arizona. An interesting extension that would strengthen this manuscript would be to do a similar assessment using the 4km and possibly the 12km domain domains to see how regional ozone transport is impacted by smoothing out terrain features. The authors make a compelling case that these features are important and a fine resolution is needed to resolve the terrain, but we have not context for direct comparison with the coarser simulations.

In previous studies, Taha (2008), using MM5/CAMx, found that higher-resolution can improve model simulations on ozone concentrations in the Los Angeles area. Tie et al (2010), using WRF-Chem, found that higher-resolution improved model performance in simulating Mexico City's ozone concentrations.

To respond to the Reviewer's question, we actually have examined the effects of horizontal resolution on surface ozone concentrations. Besides CTRL runs, we have conducted two additional runs with the same model setup and configuration as the CTRL runs, but just running Domains 1, 2, and 3, whose highest resolution is 4 km. The comparisons of model performance between 1 km and 4 km resolution are listed in Table 1 in the revision version. The model at 1 km resolution performed better than that at 4 km resolution over all, especially for the correlation coefficients, normalized mean gross errors, mean normalized bias, and normalized mean error.

Table 1: Statistical results of hourly surface [O_3] from model simulations at 1 km and 4 km resolutions in Southern CA and Central AZ

	11-14, May 2012				16-19, July 2005			
	CA	CA	AZ	AZ	CA	CA	AZ	AZ
	1km	4km	1km	4km	1km	4km	1km	4km
Mean Bias (ppb)	-1.9	-3.4	0.6	-0.4	-2.0	-4.0	-4.8	-4.7
Normalized Mean Bias (NMB)	-7.9	-13.5	2.5	-1.7	-8.6	-16.3	-18.5	-18.4
Normalized Mean Error (%)	16.3	25.0	15.4	16.8	24.2	34.1	24.1	25.6
Mean Normalized Bias (%)	-6.7	-10.7	3.2	-1.2	-3.5	-9.7	-16.4	-18.5
Mean Normalized Gross Error (%)	16.7	24.9	15.9	17.3	23.8	34.0	24.5	26.2
Correlation coefficient	0.75	0.54	0.76	0.65	0.74	0.4	0.75	0.61
Root Mean Square Error (ppb)	16.1	19.9	15.7	15.5	22.9	30.1	15.8	17.2

The follow paragraph is added to the manuscript (Lines 289-300):

"To examine the effects of model resolution on surface ozone concentrations, we conducted two additional model runs. These two additional runs were set up and configured exactly the same as the 1.33 km runs; but, with just running WRF-Chem with Domains 1, 2, and 3, which means the highest resolution of model output is 4 km. The model performance at 4 km resolution was also validated against ozone observations and summarized in Table 1. As shown in Table 1, the model performed much better for the correlation coefficients, normalized mean gross errors, mean normalized bias, and normalized mean error at 1 km than those at 4 km. For the mean bias and normalized mean bias, the model performed better in southern California at 1 km than those at 4km, with similar performance in greater Phoenix. Therefore, we confidently conclude that WRF-Chem in its present configuration performed better at 1 km resolution than that at 4 km resolution based on the two events and 2005 NEI. Our results are consistent with previous studies (e.g., Taha 2008; Tie et al., 2010). In the following analysis and discussion, we mainly focus on the model output at 1km resolution."

The presentation of the contribution information could be presented more clearly if the contributions were shown as the difference between the baseline scenario and the sensitivity simulations. In Figure 5 and 6, the readers are left to interpret the contributions by visualizing the differences between the baseline and the simulations where emissions have been zeroed out. It would be also helpful if the authors clarify if the differences between the baseline simulation and the sum of the BEO, noAZ, and noCA should be only the chemical inflow into the 1.33 km domain or if that would include other sources of ozone. Spatial plots of contribution from southern California, Arizona, and the biogenics-only simulation would be very helpful in terms of understanding the amounts and gradient in contribution from these sources/areas when interpreting the results.

Figure 6 is replotted according to the Reviewer's suggestion.

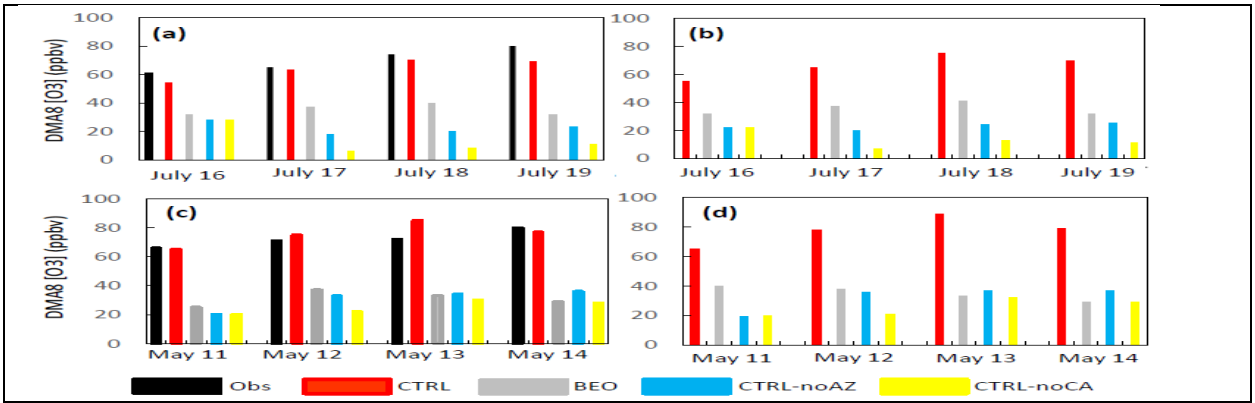

Figure 6: Mean DMA8 [O_3] in Phoenix metropolitan area from observation (Obs), simulation from CTRL runs (CTRL), BEO runs (BEO), and the relative contributions of different emission sources. CTRL-noAZ represents the modeled DMA8 [O_3] differences between CTRL run and noAZ run. CTRL-noCA displays the modeled DMA8 [O_3] differences between CTRL run and noCA run. Observation sites show in Figure 1b. (a) DMA8 [O_3] at observation sites for July 16-19, 2005, (b) the same as (a) but for that averaged from Phoenix urban grid cells. (c) and (d), the same as (a) and (b) but for the case of May 11-14, 2012.

Similar to Figure 6, the hourly ozone variations for different sites on May 14 and July 19 are also plotted as shown in Figures S4 and S5 for support materials.

A figure on DMA8 [O_3] spatial distributions for CTRL, noAZ, noCA, BEO, (CTRL-NoCA), and (CTRL-NoAZ) on July 19, 2005 is plotted and shown as Figure 7 in the revision veriosn. A similar figure on May 14, 2012, will be put into the supplement materials as Figure S6.

The following paragraph is added in the manuscript (Lines 380-385):

"This figure depicts the spatial distributions of DMA8 [O_3] for different emission scenarios on July 19, 2005. The CTRL run indicates that the higher [O_3] occur in the northeastern urban perimeter, which is consistent with previous studies (e.g. Lee and Fernando 2013). The effects of SoCal emissions and AZ local emissions on DMA8 [O_3] are location-dependent. The case of May 14, 2012, is also examined (see Figure S6) and a similar distribution as Figure 7 is found but it differs in magnitude."

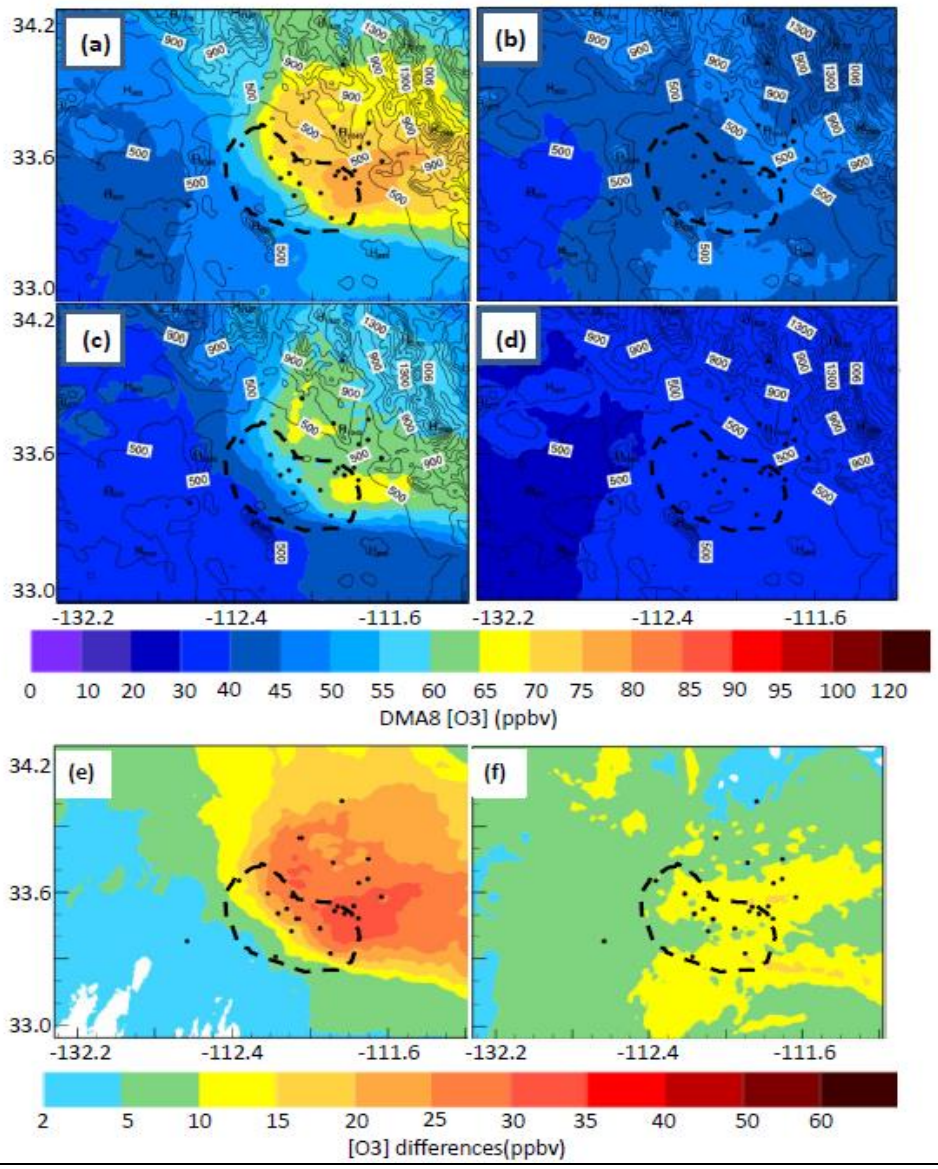

Figure 7: DMA8 [O3] spatial distributions in greater Phoenix and surround areas on July 19, 2005: (a) CTRL, (b), noAZ, (c) noCA, (d) BEO, (e) CTRL-noAZ, and (f) CTRL-noCA. Contours represent terrain elevations. Dots shows O3 observation site. Dashed-Circle indicates the approximate location of Phoenix urban area.

More emphasis is needed throughout the manuscript that these impacts are based on the 2005 National Emission Inventory (NEI)and emissions have changed since 2005 in both California and Arizona. Also notable emissions in these areas may be changing at different rates (e.g., more aggressive emission control programs in one place compared to the other, higher rate vehicle fleet turnover in one area compared ti the other, etc.). It would be ideal if the most recently available NEI was used to support this analysis, but in place of that the authors could strengthen the manuscript by providing a comparison of anthropogenic emissions in southern California and Phoenix that were used in this modeling assessment and the emissions for these areas from the 2011 NEI. This would be the best alternative to using newer emissions as part of the modeling since the authors correctly note(page 8270 Lines 16-22) that making emissions adjustments to the 2005 NEI such that the model estimates of o3 match observations does not provide a better estimate if episode specific emissions but compensates for other model specific formulation deficiencies. The authors

should also discuss any implications of 2005 vs 2011 emissions comparison to the relative contributions of Arizona and California emissions to Phoenix ozone concentrations. If the emission comparison between 2005 and 2011 suggests that the relative influence if emission from these two regions has changed in the past 10 years, appropriate caveats should be added to the abstract and conclusion sections.

Thanks for the comments and suggestions. Lines 16-22 on Page 8270 are removed. Emission changes are discussed (lines: 254-260)

"The emission comparisons between the South Coast Air Basin, California and Maricopa County, Arizona for years 2005 (red) and 2011 for Maricopa County and 2012 for South Coast Airshed (blue). Relative to 2005, anthropogenic emissions of CO, NOx, and VOC are reduced 40-50% in 2012 in the south coast airshed, California, explaining why the [CO] and [NOx] were overestimated. However, the changes in Maricopa County are not significantly except CO from Mobile."

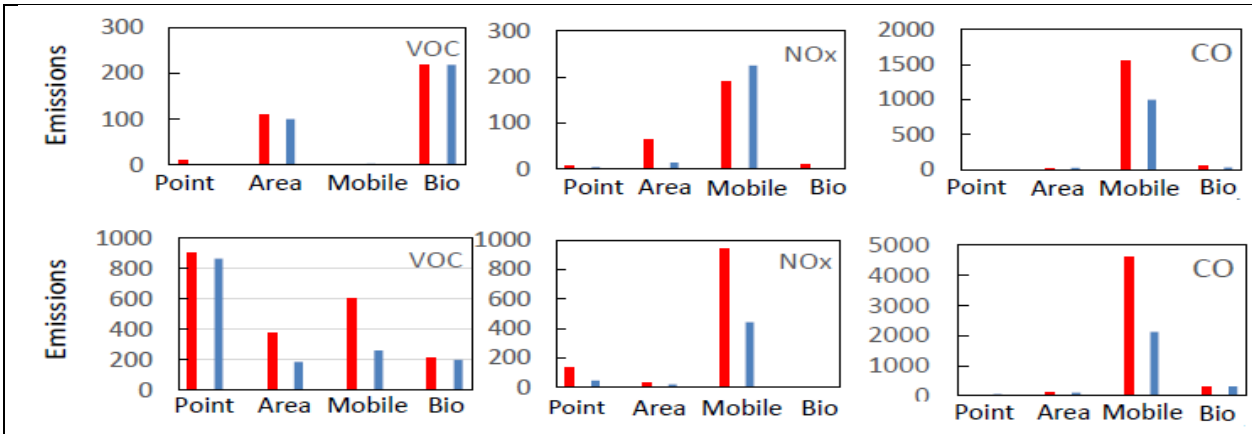

Figure S2: Emission (Ton per day) comparisons in Maricopa County (top panel), Arizona, and South Coast Airshed (bottom panel), California, between 2005 (red) and 2011(blue) for Maricopa County and 2012(blue) for South Coast Airshed. In South Coast Airshed, emissions from Mobile in 2012 are reduced significantly (40-50%), relative to 2005. The emission variations can explain why WRF-Chem overestimated the ozone precursors in the May 2012 case. In Arizona, CO emissions from mobile are reduced. NOx emissions are reduced for area sources but actually increase for mobile sources.

"South Coast emission data are downloaded from http://www.arb.ca.gov/app/emsinv/fcemssumcat2013.php.

Maricopa County emission data are downloaded from http://maricopa.gov/aq/divisions/planning_analysis/emissions_inventory/Default.aspx ."

The caveat that "the results are based on NEI 2005" is also added in the abstract and conclusion.

The U.S. Environmental Prediction Agency has published modeling guidance in 2007 (U.S. Environmental Protection Agency, 2007) and more recently at the end of 2014 (U.S. Environmental Protection Agency, 2014) that should be used place of older guidance from 1991. As noted in the 2007 and 2014 modeling guidance documents U.S. EPA has no criteria for "acceptable" model performance (U.S. Environmental Protection

Agency, 2007, 2014). The Agency recommends comparing model performance results (performance metrics such as bias, error) to those estimated in other similar contemporary model applications. The authors note quite a few relevant modeling studies done for the southwest U.S, in the introduction section so the most relevant model performance would be to compare the results here to those studies where possible. Additionally, in the absence of the relevant contemporary studies, model performance results here could be compared to recent review paper (Simon et al, 2012) that compiled model performance statistics for regional and local scale O3 and PM2.5 photochemical model simulations.

Thank you for the comments. The comparison is added in Table 1 and the following text (Lines 280-288):

"Table 1 presents the statistics of comparisons of surface ozone concentrations between the model and observations in southern California (total 46 sites) and greater Phoenix area (total 24 sites), respectively. These statistics shown in Table 1 are widely used in evaluating model performance (Simon et al., 2012). Our statistics are comparable with those from previous studies in the two regions. For example, in southern California, the mean biases, RSME and correlation coefficients shown in Table 1 are comparable with those from Huang et al.(2013, their Table 3) and Chen et al. (2013, their Tables 2 and 3). Furthermore, the mean normalized bias and mean normalized gross error are comparable with those from Taha (2008, in his Table 2). In greater Phoenix, these statistics are generally comparable with those from Lee et al. (2007), and Li et al. (2014)."

Since the goal of these simulation is to assess interstate transport from California to Arizona and that could take several days, the episodes seems rather short especially when combined with exclusion of only a single day at the beginning of the episode for spin-up. Are these periods of elevated ozone only for a single day or would it be possible to relax some of the episode criteria and include more days in the analysis?

A: In the manuscript, most of the figures (such as Figures 2, 3, 4, 5, 6, 7, 8, 10 and 11), analysis, and discussion are based on multiple days or multi-day means. In Figures 9, 12 and 13, which show specific time periods in a single day, we mainly want to show the transport of the front , because, compared with other days, this day has an especially clear frontal movement.

Some additional information regarding the methodology would be useful. Was the analysis nudging used for any of the domains in WRF? If so, which domains and which variables where nudged (above and below PBL?). What us the vertical grid structure used in the analysis? Was the MOZART simulation for 2005 or some other year?

The relevant information is added in the text (Lines 212-213; Lines 167-168; Line 177-179).

"In addition, analysis nudging is applied for the meteorological fields (U, V, T, GPH, and Q) above the PBL in the outer most domain for the first 24 hours."

"The vertical configuration of the model comprised 41 vertical layers: The lowest 15 layers are within 1500 m a.g.l. and the first half-vertical layer above ground level is 12.5 m. a.g.l."

The atmospheric chemical boundary and initial conditions are obtained from MOZART-4/GEOS-5 (http://www.acd.ucar.edu/wrf-chem/mozart.shtml) for the 2012 case and from MOZART-4/NCEPT42 for the 2005 case (Emmons et al., 2010).

I appreciate that this suggestion generally outside of the scope of this project, but since the authors made effort to model Phoenix at 1,33km grid resolution it would be interesting if some information could be presented

about the urban gradients and variability in ozone on these episode days. Are local emissions features seen in the model results (e.g., large point sources, highways etc.)? Spatial plots for the metropolitan area for baseline simulation and the sensitivity simulations showing contribution from southern California and Arizona could be of interest.

A spatial distribution plot for July 19, 2005, has been plotted as shown as Figure 7 and the other plot for May 14, 2012, Figure S6) is put into supportive materials. Due to diffusion, dispersion, and advection, the plots still cannot resolve these local emission features, even at 1.33 km resolution, partly because our 1.33-km grids with their emissions had to be interpolated from the 4 km NEI-2005.

The ozone gradients and variability at the metropolitan scale can be clearly seen (Figure 7, and Figure S6).

Figure 1. The lower panel is nicely presented. However, the political boundaries are hard to make out.

Thank you. Figure 1 is re-plotted.

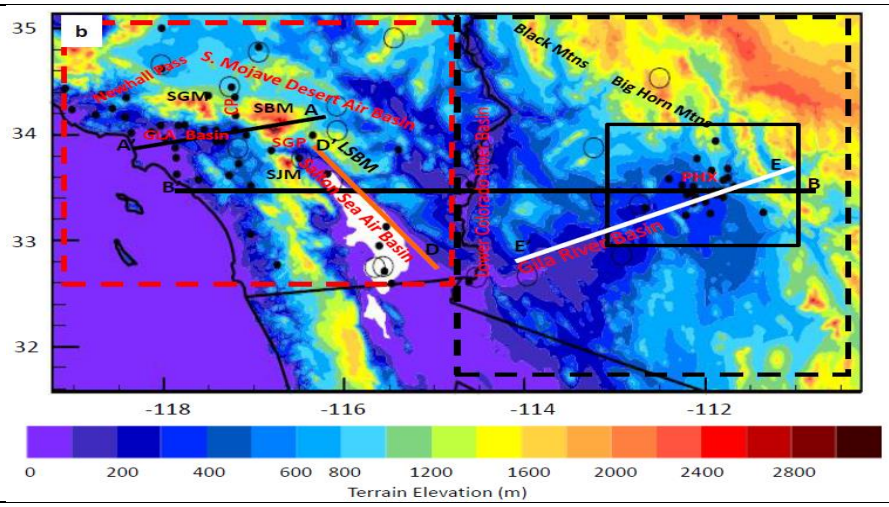

Figure 1b: Terrain elevations (m).

Figure 2-4: There is a lot of useful information presented in these time series plots. However, the information is difficult to differentiate. Perhaps using different line types (dashed etc) could help make these easier to interpret or presenting the information as a time series of blox plots.

Figure 2, 3, and 4 are re-plotted. The data are hourly data and make it hard to plot a extremely clear time series.

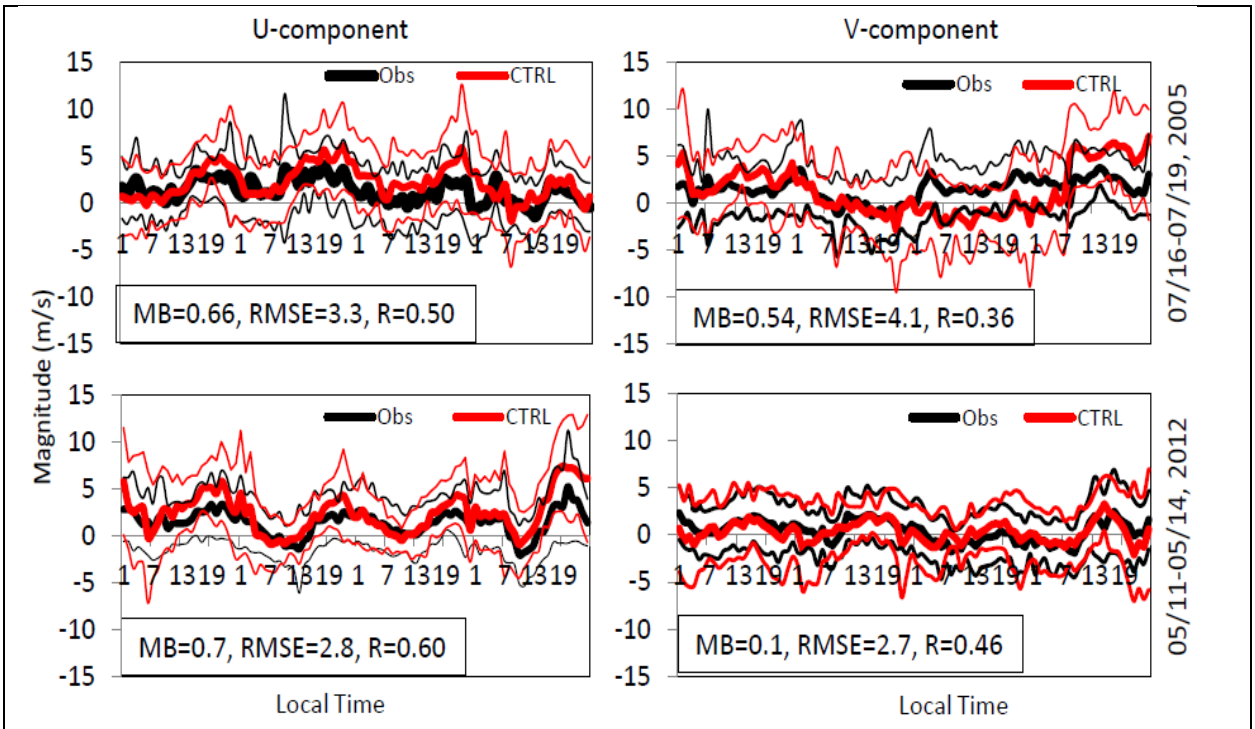

Figure 2: Surface wind comparisons between simulations (bold-red) and observations (bold black). There are totally 20 sites, including those in CA and AZ with locations shown in Figure 1b as circles. The variation ranges of simulation and observation are correspondently labeled by thin-red-line and thin-black-line, respectively. Mean Biases (MB), RMSE and correlation coefficient (R) are labeled also. CTRL represents WRF-Chem control run.

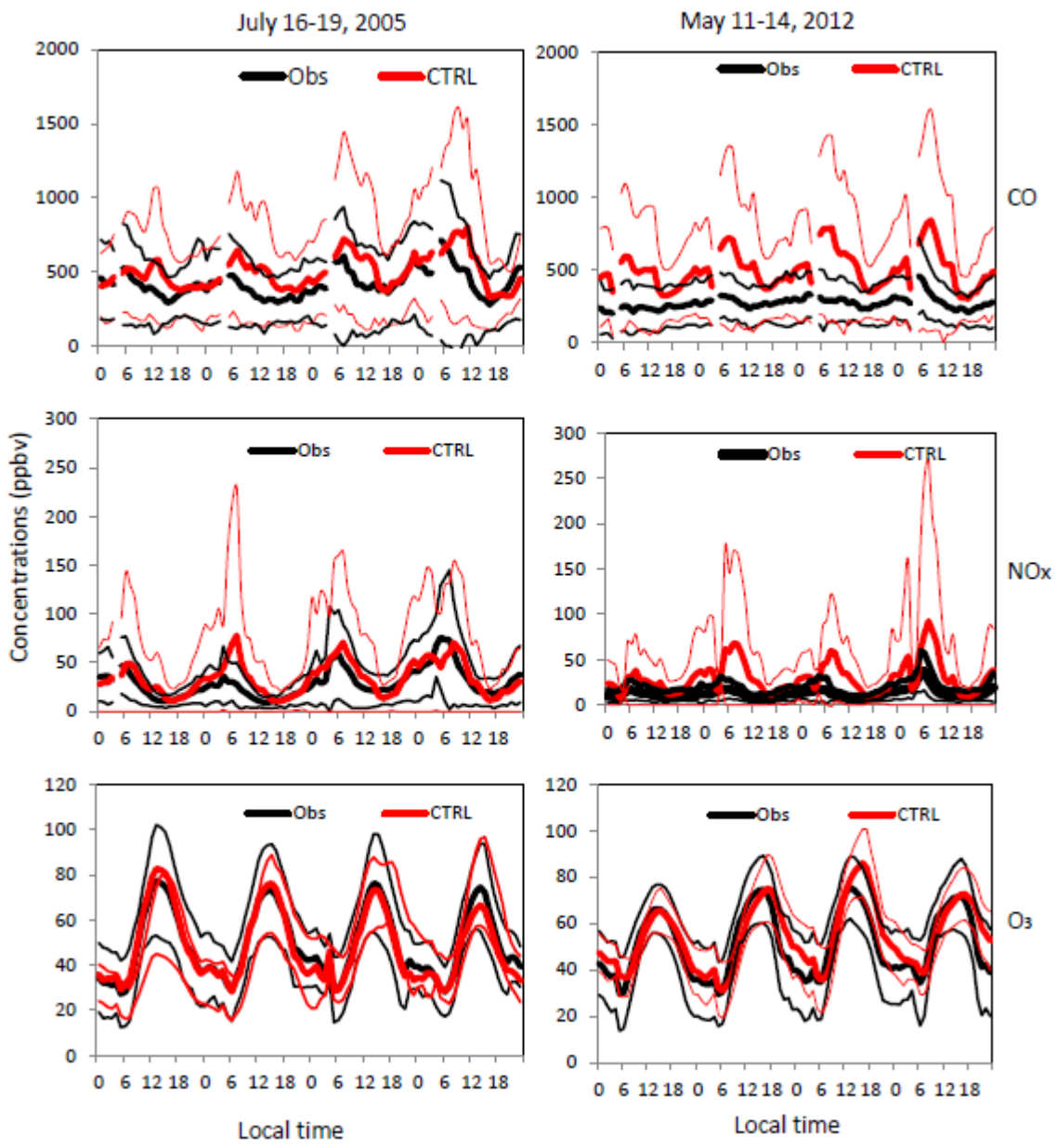

Figure 3: The comparisons of CO, NOx, and O_3 concentrations between observations (bold black) and simulations (bold red) in Domain 4. There are 23 sites for NOx, 20 sites for CO, and 65 sites for O_3 observations during the study time periods. The locations are shown in Figure 1b. The variation ranges of simulation and observation are correspondently labeled by thin-red-line and thin-black-line, respectively. Missing observation time (4:00 local time) is masked in the figure. CTRL represents WRF-Chem control run.

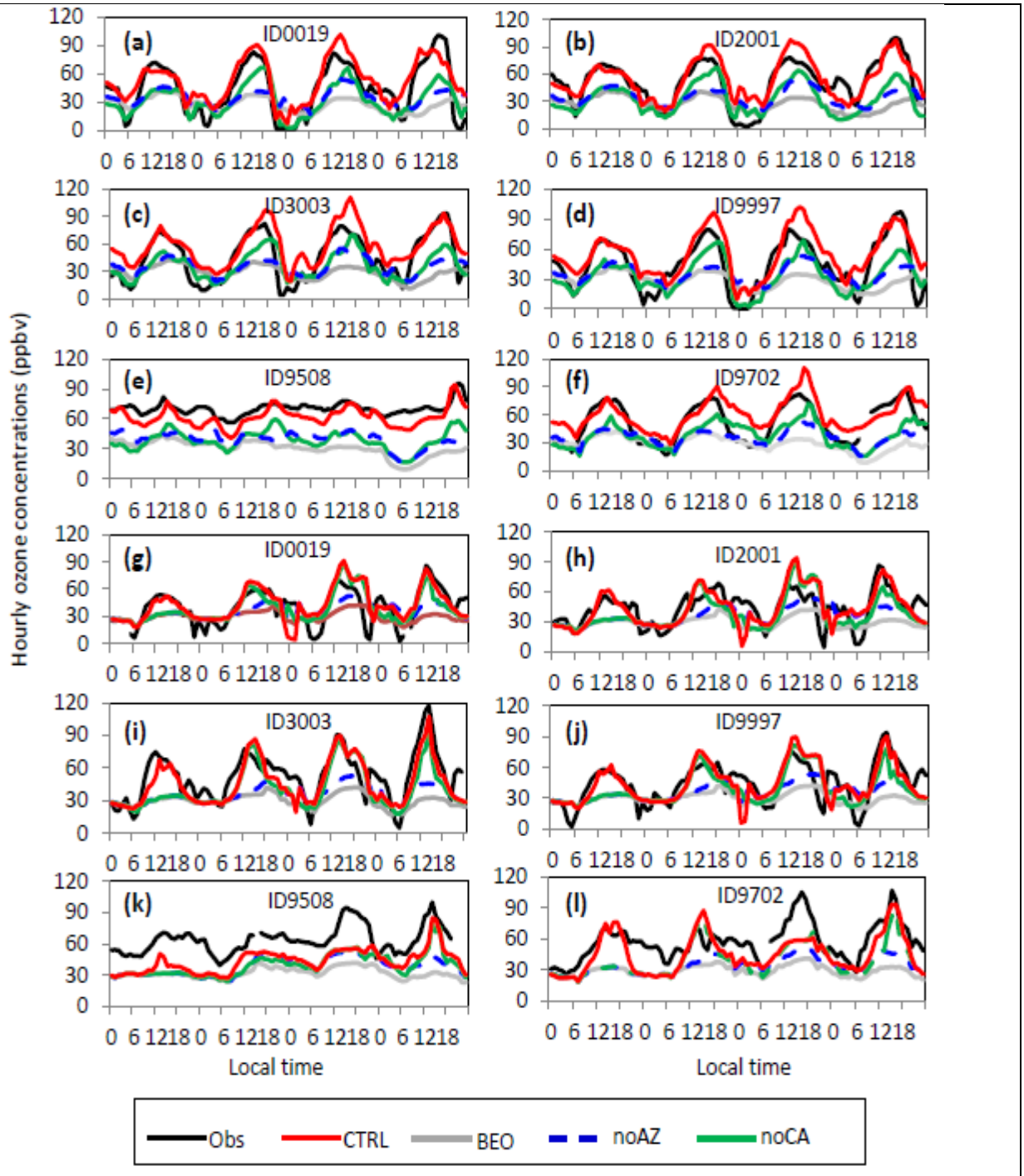

Figure 4: Relative contributions of different emission scenarios to [O_3] at observation sites in Phoenix metropolitan area and surrounding rural areas. The dates are May 11-14, 2012 (Figure 4a-4f) and July 16-19, 2005(Figures 4g-4l). Idxxxx corresponds to the EPA AIRS site number in Maricopa County, Arizona. Black line indicates the [O_3] observation. Red line represents the simulated [O_3] for the CTRL run. Dashed-blue line shows the [O_3] for the noAZ run. Green line displays the [O_3] for the noCA run. Gray line is the [O_3] for the BEO run.

Figure 6. This may be easier for those less familiar with the material to interpret if there were only 3 sets of bars: observation, baseline (control) total, and then a stacked bar showing the contributions from BEO, noAZ, and noCA in different color.

Figure 6 is replotted in response to reviewer.

Due to non-linear interactions among chemistry, emissions, physics and dynamics and/or due to the uncertainties of the emissions and models themselves (Kwok et al., 2014). The stacked bars wouldn't work because the differences are not additive.

Figures 7, 8, 9, 11, and 12: These are really nice Figures. On some of them, the political boundaries are a little hard to see. It would be really interesting to see comparable Figures with the 4 km and maybe the 12 km simulations to see how the lack of orographic resolution impacts these features (could be put in supporting information to avoid large re-writes to the manuscript).

The spatial figures are replotted (Figure 1, Figure 12) and the political boundaries are much clearer now. Relevant 4-km resolution plots are analyzed and some examples are shown here (details on Figure S7, S8, S9, S10, and S11 are shown as supportive materials).

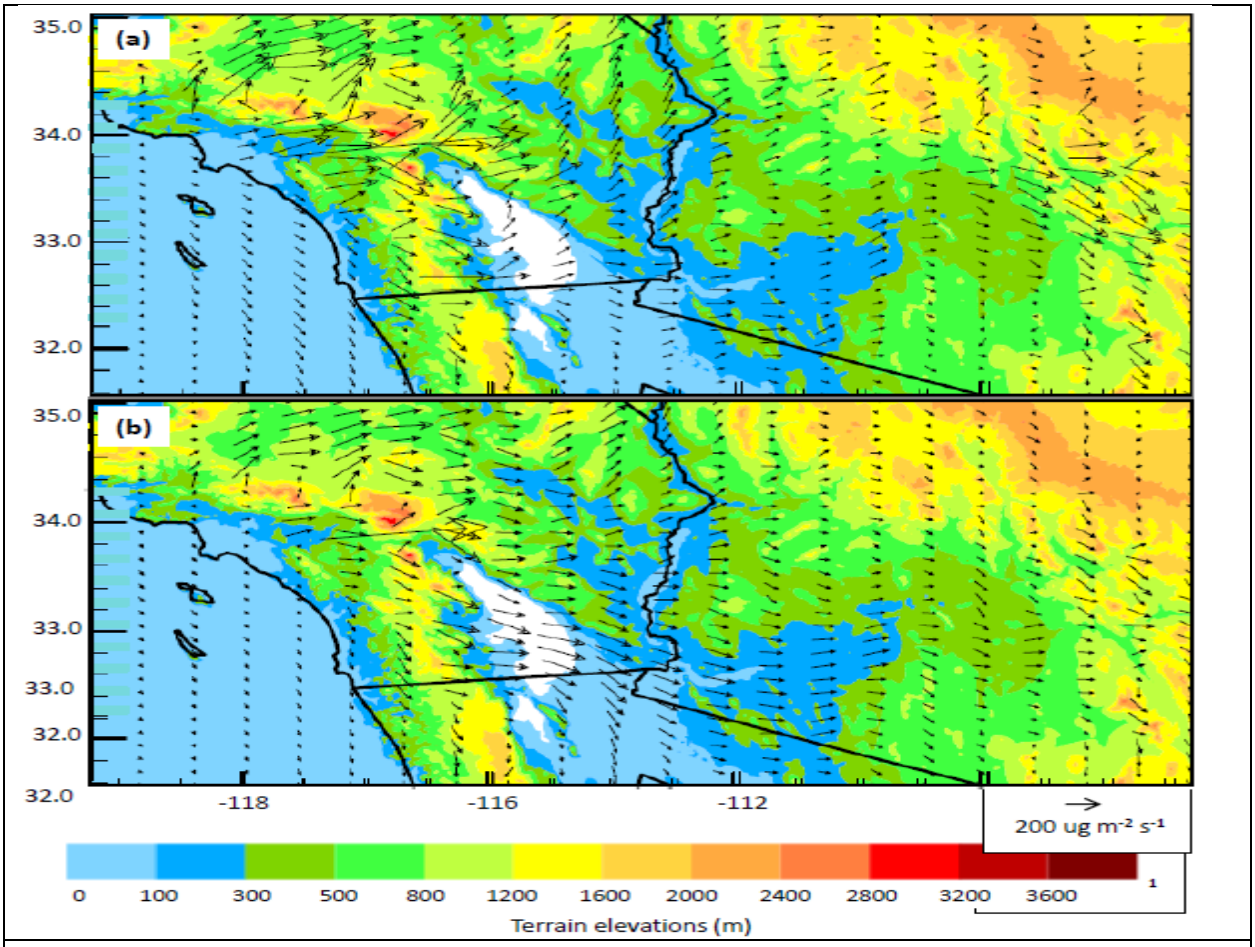

Figure 12: Integrated fluxes of ozone differences (CTRL-noCA) from surface to 1400 m above ground-level: (a) average from 18Z to 02Z, July 16 to July 20, 2005, and (b) average from 03Z to 17Z, July 16 to July 20, 2005

Figure 12 and Figure 13 are the same.

Thank you and now corrected (now Figure 14).

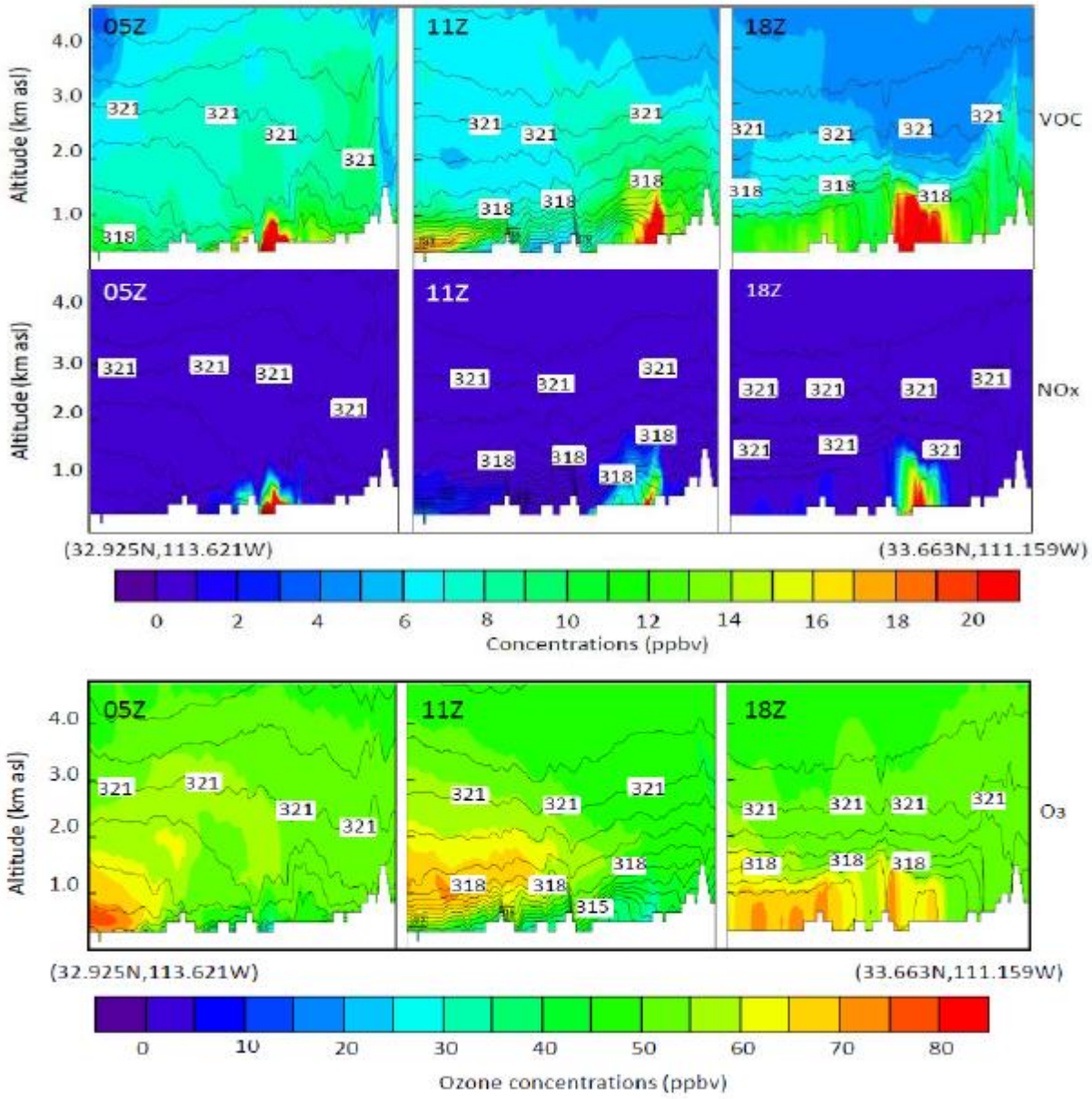

Figure 14: The vertical distribution of VOC (top), NOx (middle), and O_3 (bottom) along the cross-section D'D (shown in Figure 1b) in Gila River Basin, Arizona at 05Z, 11Z, and 18Z, July 18, 2005. Contours are potential temperature with 1-K interval.

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