Interactive comment on "Impact of external industrial sources on the regional and local air quality of Mexico Megacity" by V. H. Almanza et al.

Anonymous Referee #2

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In this paper, the authors aimed to investigate how the air quality in terms of SO2 is affected by emission reductions by two major external contributing sources by taking Mexico City Metropolitan Area (MCMA) as a case study. Basically, they utilized the WRF-Chem model nudged with surface observations from RAMA as well as surface and wind profiles from MILARGO campaign to determine an optimum model configuration and then perform sensitivity tests by taking into account five emission scenarios involving different emission reduction strategies. The model results suggest that "reductions in both external sources by 2017 tend to affect more the northern part of the basin (-16.35 to -45.58 %), whilst reductions of urban sources by introducing high quality fuel in the megacity tend to greatly diminish SO2 levels in the central, southwest, and southeast regions (-30.71 % to -49.75 %)". This indicates that "a combination of technological changes in external sources could drive long-term changes in urban sources within the megacity, which in turn could result in lower levels of SO2". They also evaluate the influence of TIC region to ozone levels. Overall, this is interesting study appropriate for the scope of Atmospheric Chemistry and Physics. However, some issues with respect to datasets and method descriptions sound vague. I think the clarification of these issues is critical to understand comprehensive results presented in this study. For instance, they neglected the consideration of aerosol module in the WRFChem simulation. This may bring a large uncertainty since SO2 is easily oxidized to sulfate aerosol in the air. Additional simulations may be required to address this issue.

Moreover, the quality of figures needs to be improved while the context needs some rearrangement. Hence, a major revision of the manuscript is recommended before the publication in ACP by addressing my following comments.
Specific comments:

1. In this study, the authors chose the last week of the MILAGRO campaign as a study episode (i.e., the period from 00:00 UTC March 22 to 00:00 UTC March 28). de Foy et al. (2009) show there are multiple peaks of SO2 emissions along the entire MILAGRO campaign (e.g., March 4, March 18, etc). I am curious the reason the authors choose the last week as the study episodic event since the amount of SO2 on March 18 is almost twice as much as that on March 25 (de Foy et al., 2009). I am also curious if the influence from TIC (MHR+FPRPP) and cement plants on the MCMA SO2 and O3 level would change if choosing different episode.

de Foy, B., Krotkov, N. A., Bei, N., Herndon, S. C., Huey, L. G., Martínez, A.-P., Ruiz-Suárez, L. G., Wood, E. C., Zavala, M., and Molina, L. T.: Hit from both sides: tracking industrial and volcanic plumes in Mexico City with surface measurements and OMI SO2 retrievals during the MILAGRO field campaign, Atmos. Chem. Phys., 9, 9599–9617, doi:10.5194/acp-9-9599-2009, 2009.

Response:
The simulation episode was chosen for the following reasons:

1. The strongest cold surge of the MILAGRO campaign occurred during this period (Fast et al., 2007; de Foy et al., 2009). This promotes higher impacts from point sources located north of Mexico City, including the Refinery and the power plant in Tula, State of Hidalgo, and Cement Plants in the State of Mexico. Usually, during these meteorological events the industrial plume impinges directly in the MCMA affecting the air quality in the basin since the transport can last for several hours.

2. During this period, an SO_2 peak was observed in most of the stations in the north of the basin. The model simulations did not reproduce this emission event in both our previous study and in the present work. We considered worthwhile to explain this peak since neither the inclusion of data assimilation nor the plume from the major emissions sources could explain it. This suggests the possibility of additional emission sources, in particular those in Tizayuca region, which can be considered and analyzed with greater detail in future studies.

3. This period presented no contribution from the Popocatepetl volcano, as previously shown by de Foy et al. (2009) and confirmed by our model simulations. This allowed us to run fewer simulations and to focus on industrial and urban sources, saving disk space and computing time.

As it was suggested by the reviewer, we obtained the contribution of the emissions of the TIC, MCMA and cement plants on 18 March and compared it to the contribution on 23 March. However, this study focuses on the influence of the cement plants on sulfur dioxide levels. For that reason, their influence on ozone levels will not be addressed in this work. Please see our reply to Comment number 2.

2. P.26587 l.4-5, the authors stated to neglect aerosol chemistry in the present work and they just simply assumed that "the conversion to sulfate aerosol has a small impact in the final model concentration" without any justification. According to Karydis et al. (2011), very high sulfate concentration (over 25 ug/m3) was found during the MILAGRO campaign. Moreover, SO2 can be easily oxidized to SO4(2-) in the air. I am curious to know the difference in the predicted model concentration if the aerosol chemistry module is switched on compared to those presented in this work. Please provide the quantitative justification using the WRF-Chem model.

Response:
To address this comment our original model configuration had to be modified in order to include aerosol chemistry. In addition, Fast et al (2009) mentioned that treatments for aqueous chemistry, cloud-aerosol interactions, aerosol indirect effects, and wet deposition could have been important after the third cold surge. For this reason we considered worthwhile to include these processes in our aerosol simulations. These model parameterizations require the Goddard scheme for the shortwave radiation module; however, in our original model configuration we used the Dudhia scheme. Thus, the objective of these simulations using the Goddard scheme is to determine the

effect of including the aerosol module on the modeled average SO_2 and ozone concentrations. We used the MOSAIC module with 4 bins in order to reduce computing time.

This part is organized as follows. Section 1 presents the results with the inclusion of the aerosol phase in WRF-Chem. Section 2 presents the results of the effect of the aerosol phase on the contribution of cement plants. Sections 3 and 4 briefly address the contribution of cement plants on 18 March and on the reduction scenario S5. Section 5 presents the results for the regional ozone levels.

1. Inclusion of the aerosol phase

A new baseline case for the gas phase was constructed. The difference with the baseline case reported in the manuscript is that the Goddard scheme for the shortwave radiation was used instead of the Dudhia scheme. The purpose of the simulations was to better depict the influence of the aerosol phase on the modeled average SO_2 concentration. The same input files for both the emissions inventory and Multiscale Four Dimensional Data Assimilation (FDDA) that were used in the original configuration were also used in all the aerosol simulations. Just for consistency purposes, it was decided to also include aerosol simulations without the inclusion of direct and indirect effects to better depict the influence of the aerosol module on the modeled concentration. It is important to mention that we are not attempting to quantify either the direct or the indirect effect. It is beyond the scope of this work. Results are presented in Figure 1.

Figure 1 shows the estimated average SO_2 concentration during the simulation period for the considered simulation cases. The notation is as follows: **BCg** denotes the original baseline case configuration for the gas phase which was presented in the manuscript; **BCa** denotes the original baseline case configuration presented in the manuscript but with the aerosol phase turned on; **BCGg** denotes the new baseline case configuration for the gas phase using the Goddard shortwave radiation scheme; **BCGa** denotes the configuration using the Goddard shortwave radiation scheme with the aerosol phase turned on; and **BCGs** denotes the configuration using the Goddard shortwave radiation scheme plus the inclusion of the aerosol direct and indirect effects. **OBS** denotes the average observed concentration at each monitoring site.

After including the aerosol phase in WRF-Chem and comparing the simulations with respect to the baseline case configuration, the results suggested a slight increase in the model average SO_2 concentrations in most of the monitoring stations. However, in the northwest region the average SO_2 concentration slightly decreased (BCa). When using the Goddard scheme (BCGa), the SO_2 concentration also decreased in the northwest and in the southwest region as well. Nevertheless, it slightly increased in the northeast and southeast regions of the basin. In contrast, after including the direct and indirect effect (BCGs), the average concentration tended to increase in the northwest, and in part of the center and southwest regions. Even though the average concentration slightly increased in some regions of the basin, the resulting magnitude in all the simulation cases was relatively comparable to the results presented in the manuscript. This is better depicted in Figure 2. The figure shows the results when taking the arithmetic difference between the average concentrations obtained after including the aerosol phase and those obtained with the gas phase. The notation in Figure 2 is as follows: **BCag** denotes the difference between

the results with aerosol phase and the results with the gas phase using the Dudhia scheme of shortwave radiation; **BCGag** denotes the same difference as in the previous case but using the Goddard scheme of shortwave radiation; **BCGsg** denotes the difference when including the aerosol direct and indirect effects using the Goddard scheme. The last three plots are included to show the difference between the results of all the cases using the Goddard scheme and the original results presented in the manuscript. Thus, the notation is similar: **BCGg-BCg** denotes the difference between the two baseline cases; **BCGa-BCg** is the difference between the aerosol phase case and the baseline case of the manuscript and **BCGs-BCg** is the difference between the case including the aerosol direct and indirect effects and the baseline case.

The differences in average SO_2 concentration range from about -0.3 ppb and 0.5 ppb, with some stations having differences of about 1 ppb. The median for all the simulation cases is about 0.2 ppb, which roughly represents a 10 % difference.
Since the radiation scheme also affects the PBL module, the inclusion of the Goddard scheme resulted in higher variability in the average SO_2 concentration as the last three boxplots suggest. In general, the inclusion of the aerosol module resulted in lower PBLs; however the Goddard scheme plus the direct and indirect effects tended to give higher PBLs on the regional scale with respect to the baseline case using Dudhia scheme and to the baseline case using the Goddard scheme. Therefore, part of the increase on the average concentration can be attributed to the shallow PBLs obtained with the Goddard scheme.

The chemical mechanism is also contributing to the observed differences. The Multiscale FDDA can also influence the model performance since it can affect the feedback processes (Forkel et al. 2012). In addition, the original results included a preliminary sensitivity analysis using the Dudhia scheme on nudging coefficients and the calculation of diffusion in physical space for the innermost domain. The main result of that sensitivity analysis was to activate the convective parameterization in the innermost domain. This implies that a similar sensitivity analysis using the Goddard scheme would have to be performed in order to determine more precisely the influence of those parameters in the final model configuration. For instance, we observed that the variability in modeled temperature increased after using the Goddard scheme and the aerosol module since the bias and MAE presented a slight increase. Wind speed was similar in all simulation cases; however, the model performance in wind direction tended to have higher variability. Using the Goddard scheme resulted in one hour delay in the timing of the simulated SO_2 concentration peak on 23 March at some monitoring stations (Figure 3).

Karidys et al. (2011) report a sulfate concentration of about 25 ug/m^3. They used PMCAMx-2008 with SAPRC99 for the period of March 10-31 2006. Despite the differences in the modeling setup and the effect of the Goddard scheme and aerosol module on the model performance, our results also suggest concentrations of PM_1 sulfate of about 23 ug/m^3 to 25 ug/m^3 over the Tula Industrial Complex as shown in Figure 4. We observed that neglecting the direct and indirect effects in the model configuration resulted in slightly lower PM_1 sulfate concentration on the regional level.

2. Cement plants

As described above, we used the model configuration which included the aerosol direct and indirect effects. Figure 5 presents the results obtained with the configuration reported in the manuscript (top panel) and the configuration with aerosol chemistry (bottom panel).

The results suggest that when using the aerosol chemistry T1 had the highest SO_2 contribution from cement plants emissions during the simulation period, whereas in the original results the highest contribution was estimated at VIF station. That is, the average contribution at T1 increased from 41 % to 52 %. In general, it was observed an increment ranging from 2 % to 10 % in the contribution from TIC; a decrement ranging from -1% to -15% in the MCMA contribution and an increment ranging from 1 % to 10 % in the cement plants contribution with respect to the original results. Thus, the inclusion of the aerosol chemistry in the simulations suggested that the contribution of the TIC and the cement plants emissions to SO_2 levels could be higher and that the contribution of urban emission sources could be lower. It is important to mention that there was a consistent overprediction on 23 March and on 25 March in all the simulations with the aerosol chemistry as shown in Figure 3. The resulting magnitude was higher than the one obtained with the original configuration in most of the monitoring stations. It was observed that the model predicted a convergence zone in the original results from 17:00 LST to 21:00 LST on 24 March which prevented the plume to be transported farther to the south (Figure 6). The convergence zone extended roughly from the upper region of the western ridge to northern T1. Once the convergence zone disappeared, the plume entered farther to the northwest. This convergence zone was also present in the simulations with the aerosol phase; however, it extended to a greater area than in the original results which resulted in slightly longer time for the plume to be transported to the south. Thus, the combined effect of a shallow PBL and a wider convergence zone promoted higher SO_2 concentrations.

Therefore, the results including the aerosol phase are relatively similar to those from the gas phase. Even though the magnitude of the contributions changed, the findings reported in the manuscript are not modified substantially, since both configurations suggest that the cement plants contribute mainly in the northeast and part of the southeast regions of the basin.

For this reason we have rephrased the manuscript, pg 26594 ln 1: “It shows the stations in which the urban emissions (local) are higher than the contribution of the TIC and cement plants; and those stations in which cement plants contribute more than urban sources and the TIC.”

3. **Contribution to SO_2 levels on 18 March**.

The contribution of the TIC, cement plants and urban sources on SO_2 levels is briefly addressed in this section. It focuses only on 18 March. The simulations were done with the aerosol phase plus the aerosol direct and indirect effects. The necessary files for the Multiscale FDDA were constructed as mentioned in the manuscript. They were based on the FNL final analysis, WRF’s objective analysis (OBSGRID) using the Cressman method and NCAR archives ds464.0 and ds353.4 Surface analysis fields for surface nudging were generated at 1-hour interval.

In order to compare the suggested contribution for this day it was decided to use the results for 23 March, since as previously mentioned there was a consistent overprediction on 25 March. Results are presented in Figure 7.

As our results and those reported by de Foy et al. (2009) indicated, on 18 March the Popocatepetl volcano contributed to the SO_2 levels in the basin. However, we did not perform simulations to quantify the contribution of the volcano for this day, but it can be of the order of one tenth of the total concentration (de Foy et al., 2009). The model suggests that the highest contribution in the northern region comes from the TIC, and that urban emission sources were more important in the southern region. The cement plants had a small contribution in the basin but it was relatively high at T1. In contrast, on 23 March the contribution of cement plants was more important in the northeast region as suggested in both the original results with gas phase and in the simulations accounting for the aerosol phase.

4. Emissions reduction scenarios

The influence of the aerosol phase was also investigated for the emissions reduction scenarios, focusing on the S5 scenario which includes the reduction in both external and local sources. The simulations included the aerosol phase plus the direct and indirect effects. Figure 8 shows that results with the aerosol phase are in agreement with those reported in the manuscript. The differences in contribution percentages range from -1.5 to 6; however, after the inclusion of the aerosol phase it is still suggested that the combined reduction in external and local sources would be more efficient for reducing the SO_2 levels in the basin. In addition, the southern region would be more sensitive to this set of reductions. Thus, our assumption of a small influence of the aerosol phase in model results for SO_2 is likely to not affect the main findings reported in the manuscript for the contribution of external sources and in the emissions reduction scenarios.

5. Regional ozone

It was observed that after including the aerosol phase the variability in the ozone model concentration was higher than in the SO_2 model concentration. In this case, the meteorology exerted greater influence on the transport of precursors so that larger differences in the spatial distribution were present for the ozone plume. When comparing the baseline cases for the gas phase on 25 March, the results using the Goddard scheme presented slightly higher concentrations in the basin than the results obtained with the Dudhia scheme. In the late afternoon, the ozone plume from TIC-generated precursors using the Goddard scheme reached the southern part of the basin; whilst with the Dudhia scheme the ozone plume tended to remain more in the north region of the basin (Figure 9).

Even though these differences in the spatial distribution resulted in low concentrations, the effect of meteorology on the ozone plume transport was enhanced when including the aerosol phase. Basically, the highly coupled feedback effects resulted in changes in wind direction that promoted a slightly different ozone distribution between the simulation case considering all the

point sources and the simulation case without TIC-generated precursors (Figure 10). This resulted in regions with either high or low difference in ozone concentration. However, the average difference for the entire period between the simulation with aerosol phase and the baseline case reported in the manuscript is of about ± 5 ppb (Figure 11).

The inclusion of the aerosol phase suggests that the impact of the TIC-generated precursors to the regional ozone levels could decrease in magnitude in the eastern and southern regions in the State of Hidalgo for this simulation period; and could increase in magnitude in the northwest region of the MCMA. Nevertheless, a main finding in the original results was that the suggested highest contribution from the TIC occurred on 25 March. A similar result is obtained after including the aerosol phase as shown in Figure 12. Thus, despite the spatial variability the results including the aerosol phase are comparable to the original results in the manuscript obtained with the gas phase.

It can be concluded that the average concentrations of sulfur dioxide and ozone are not substantially modified after the inclusion of the aerosol phase in the model simulations for this period. For this reason, we consider that our first results are sufficiently reliable to support the discussion of this work. Nevertheless, we agree with the importance of including aerosol chemistry in air quality simulations. As a note, we also performed simulations with overlapping segments of 36 hours with 12 hours of spinup time, and used the option of exact shell approximation for the aerosol properties option. Better agreement with observations was found at some monitoring stations for ozone simulations. This will be addressed with greater detail in future studies regarding the study of emissions from flaring activities in Tula.

Based on this, the following paragraph was added on pg26587 ln 5: "Test simulations for this period (not shown) with Dudhia shortwave radiation scheme, Goddard shortwave radiation scheme and including the direct and indirect effects, suggested a difference ranging from -0.3 ppb to about 1ppb on the final average SO_2 model concentration at the monitoring stations sites. Thus, it is considered that conversion of SO_2 into sulfate has a small impact in the final model concentration for this simulation period and with this chemical mechanism. In addition, the difference in the average ozone model concentration for the entire simulation period was about ± 5 ppb. Nevertheless, the effect of the aerosol phase on these and other pollutants not considered here is an important issue and will be addressed in depth in future study."

The following paragraph was added in the Conclusions section after ln 20 in pg 26603: "Separate test simulations (not shown) using the MOSAIC aerosol module with 4 bins, together with the Goddard scheme of shortwave radiation, treatments for aqueous chemistry, cloud-aerosol interactions, aerosol indirect effects, and wet deposition, suggested a difference ranging from -0.3 ppb to 1 ppb on the average SO_2 model concentration for this simulation period with respect to the baseline case of this study. As for ozone, the differences in the average concentration for the entire simulation period of this work were of the order of ± 5 ppb with respect to the baseline case of this work. Even though the differences in concentrations are relatively small, there is uncertainty associated to the influence of Multiscale FDDA, the chemical mechanism itself and the different scheme for the shortwave radiation. This requires further research in order to analyze these processes and model parameters in greater detail. For the purpose of this article,

which is to present the importance of additional emission sources of SO_2 on the regional scale (including the contribution of Tizayuca), to suggest that the existing Tula Refinery could contribute to the regional levels of ozone and to give a first estimate of ozone formation from flaring-generated precursors, we believe our results are reliable enough to support the discussion of this work."

3. P.26590 l.4, the authors stated "The model show northeasterly wind from 00:00 LST to 12:00 LST". Could you specify which figure I should look at? It's not clearly shown in either Fig. 1 or Fig. 2. Also, it's not clear for me the locations of RAMA stations compared to the MILAGRO supersites. Thus, it's hard to understand the discussion made in the first paragraph on page 26590. Could you show the RAMA stations in Figure 1?

The sentence refers to the inspection of the modeled wind fields for that period of time. It is not related to a figure in particular. It is rephrased and now it reads: "The model suggested northeasterly wind for the period from 00:00 LST to 12:00 LST (not shown)."
The location of RAMA stations was added to Figure 1c as suggested.

4. It's confusing to connect all points with purple line in Figure 6 in which the points represent average concentration of SO2 at different stations. Also, could you move the definition of 23 RAMA monitoring stations in page 26600 to the section where you start discussing Figure 6?

The figure was changed. The paragraph is moved to pg 26593 ln 2 as suggested.

5. In page 26593, the authors stated that the highest contribution in the NW comes from TIC. That's not true for site VAL and TAC where urban sources also play role. Besides, it seems like there is high contribution from TIC for site T1. However, given in the backward trajectory in Fig. 3, the backward trajectory of T1 looks irrelevant to the external sources from TIC region. This is also shown in Figure 5 in which major emissions from TIC (orange color) does not get a chance to reach T1 although the author unclearly claimed that "under favorable meteorological conditions they can reach T1" on page 26594. Please clearly explain why T1 site has significant contribution from TIC.

The sentence is rephrased: "The model results suggest that the TIC had an important contribution in the NW; that urban sources were more important in the C, and SE regions; and that cements plants contributed in part of the NE and at the suburban supersite T1."

The high contribution from the TIC to the T1 supersite presented in Figure 6 takes into account the entire simulation period. During this period, the SO_2 plume were transported mainly to the north in the State of Hidalgo and then transported back to the south impinging directly the T1 supersite. As a result, the time series presented in Figure 4 showed a relatively high peak of SO_2 on March 23 which resulted from a direct impingement of the TIC plume, as also shown in Figure 7. As mentioned, the suggested contribution from TIC was about 46 % whereas for the cement plants the contribution was about 41 %. The similarity is mainly due to the transport of the merged plumes of the TIC and cement plants to the south. Figure 7 shows what we meant by favorable conditions: north-northwesterly and northeasterly wind flow enhanced by the cold surge which promote a direct impingement of the plume at the supersite. This is the reason for

investigating the impacts of additional point sources that due to their proximity to the TIC can be overlooked.

The backward trajectories presented in Figure 3 corresponded to a short period: from 10:00 LST to 00:00 LST as mentioned in the manuscript. Figure 5 shows indeed the reason for estimating the backward trajectory, since in the early morning on 24 March the plume from the TIC did not reach T1, yet there was a relatively high concentration peak in that period that could only be explained by sources in the Tizayuca region.
The paragraph in page 26594 ln 4 now reads: "As a result, the emissions from TIC and possibly Atotonilco could be transported to the northwest, whilst those from Apaxco could be transported to the northeast passing Sierra de Guadalupe and under meteorological conditions enhanced by the cold surge, mainly north-northwesterly and northeasterly wind transporting the plume to the south, reaching T1."

6. Could you define the TIC contribution to regional ozone levels given in Figure 8? How does it relate to the total regional ozone? In other words, how do you separate the TIC contribution to regional ozone levels from other external or local sources? Also, can you make the color bar exactly same for all subplots shown in Figure 8 (with warm and cold color representing positive and negative values, respectively)? The current version look very confusing by using different color bars. In contrast to this absolute contribution (given in Fig. 8), could you also provide the relative contribution (fraction) to the total ozone concentration?

The contribution from TIC to regional ozone levels was estimated with respect to the baseline case. The baseline simulation contains all anthropogenic emission sources. We compared the results of a simulation that removed the emissions from the TIC against the baseline simulation to estimate the impact of the precursors emitted from the existing Refinery on the regional ozone levels.
The color bars were changed and zoomed into a smaller area as suggested by Referee # 3.

7. Section 3.2.3, the ozone formation is also related to NOx (and VOC) available in the air. Specifically, HNO3(gas)/NO3-(aerosol) coexist in both gas and particulate phase. Back to your assumption without including aerosol module, it would be interesting to know how the modeled ozone levels change when including aerosol module in the WRF-Chem model simulation.

Please see reply to comment # 2.

8. What does the blue curve in Figure 9 stand for?

It represents the modeled ozone contribution of the TIC with respect to the baseline case.

9. The subsection from page 26599 line 1 to page 26602 line 2 (Figure 10) is related to SO2. I would suggest moving this discussion to somewhere prior to the discussion on the ozone formation (Section 3.2.3). It's not relevant to ozone formation at all.

Please see reply to comment # 3 from Referee 3.

10. Since the major discussion in this manuscript is on SO2 and ozone instead of all substances in the air (e.g., NOx, particulate matter, etc), I think it would be accurate to have a title like "Impact of external industrial sources on the air quality in terms of SO2 and O3 in Mexico Megacity".

The title is modified as suggested. Now it reads: "Impact of external industrial sources on the regional and local air quality of Mexico Megacity in terms of SO_2 and O_3"

Technical comments:

1. Page 26580 line 14, define "NE" region.

It is defined as suggested.

2. Page 26580 line 23, define "CFD".

This line was removed according to comment # 5 of Referee 3, since this calculation is from a separate study.

3. All labels and texts in Figure 1 are too small. I can barely see the location of sites. Could you enlarge the font size? What does the shaded brown area in Figure 1c?

The font size is increased in Figure 1. The shaded area denotes the extent of the Mexico City Metropolitan Area. We found an error in the name of the Power Plant located in the MCMA. It should read Valle de Mexico Power Plant. This was corrected in the manuscript and in the figures accordingly. In addition, the Figure's caption was rephrased since the location of the Sierra de Guadalupe was added in order to follow the discussion of the wind fields in Section 3.2.2.

Now it reads: "Figure 1. WRF-Chem modeling domains: a) outer domain encompassing Mexico and nested domains. (d02 and d03); b) Inner (d03) domain showing the location of MILAGRO supersites (orange), FPRPP (violet), Miguel Hidalgo Refinery (MHR; green), cement plants (yellow), Tizayuca (TIZ), Atotonilco (ATO) and Tulancingo (TLNCNGO) municipalities in State of Hidalgo (cyan), Apaxco (APAX) municipality in State of Mexico (purple) and Valle de Mexico Power Plant (VMPP; blue). The square denotes the Tula Industrial Complex (TIC). In addition, the approximate locations of the Tuxpan Power Plant and Poza Rica Industrial Complex (magenta) are shown in d03; c) Detail of the extent of the Mexico City Metropolitan

Area (light brown) and location of the Sierra de Guadalupe (SG) in the inner domain d03. Note that the cement plants in Atotonilco, Tizayuca and Apaxco are super-imposed over the respective municipalities, that the color of supersites locations is different in panel c), and that the names do not necessarily corresponds to the exact location for better readability."

4. Also, please enlarge all labels or texts in all figures. They are too small to be acceptable for the publication. For example, I have to enlarge the original Figure 1 like 200% - 400% to see the labels or texts shown in the figure.

The font size is changed in the figures.

5. The statement in p.26582 l.22- p.26583 l.18 sounds more like the description of methods used in this study and can be moved to the section of methodology.

The corresponding paragraphs were reorganized. Please also see comment #1 from Referee 3.

6. The subsection "1.1" (from page 26584 line 19 to page 26585 line 2) sounds very strange in the Section of introduction. Maybe the authors could consider to move it to the section of methodology.

In this case, it was decided to leave this subsection as numbered in the manuscript. The main reason is because in the methodology section we focus on the description of the Model setup. We consider that the current subsection helps in presenting the region where the main industrial sources are located in, as well as in setting the context for some of the terminology that will be used later in the manuscript.

7. The subsection "2.1" and "2.1.1" seem redundant in Section 2. Could you combine them into one?

These sections were merged into one single section as suggested.

8. P.26588,l.13, what does "a.g.l" stand for? Above ground level?

Yes. It is correct. The definition was included.

9. P.26592,l.3, specify green solid or dash line in the context.

The sentence now it reads: "Taking the emission event as an area source (green dashed line) tends to increase the magnitude of the peak. This scenario was further explored with WRF-Chem (thick gold solid line)."

10. Please clearly define NW, SW,NE, SE, C in the context.

The acronyms were defined the first time they were used in the manuscript.

11. Please define PAHs on page 26595.

It is defined. Now it reads: "As part of MILAGRO campaign, studies related to SO_2, NO_2, Polyciclic Aromatic Hydrocarbons (PAHs) and metals have implicated the influence of Tula industrial corridor in the local and regional air quality"

12. Is "Flaring" a subsection as 3.2.4 on page 26597?

Yes. Please see comment # 9.

13. There are so many acronyms in the text and figures, could you define them when you start using them for the first time?

The acronyms were reviewed in the manuscript.

References

de Foy, B., Krotkov, N. A., Bei, N., Herndon, S. C., Huey, L. G., Martínez, A.-P., Ruiz-Suárez, L. G., Wood, E. C., Zavala, M., and Molina, L. T.: Hit from both sides: tracking industrial and volcanic plumes in Mexico City with surface measurements and OMI SO2 retrievals during the MILAGRO field campaign, Atmos. Chem. Phys., 9, 9599-9617, doi:10.5194/acp-6-2321-2006, 2009a.

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