

## **Answers to the second review of reviewer #2 regarding the paper named “Air quality forecast at kilometer scale grid over Spanish complex terrains” by M.T. Pay et al.**

We would like to thank the reviewer for his/her feedbacks and remarks in this second revision. We have carefully taken into account all his/her comments, which have contributed to significantly increase the quality of the paper.

Concerning the use of language and grammar, we would like to highlight that the manuscript was revised by a native speaker after the first revision, and we consider that the comments of the reviewer in this second revision are more related with a personal style of writing than with a proper use of English. Nevertheless, we have implemented all of the styling corrections suggested by the reviewer.

Please, find in the next paragraphs answers and changes introduced in the manuscript related to each of the reviewer's comments.

Reviewer: P1, L9: “the European urban population was exposed to PM10 concentrations above the daily limit value, and nearly 88% was exposed to the respective WHO AQG”. Replace “was” by “were”.

Authors: The correction has not been amended because population is a singular name.

Reviewer: P1, L30: “Future work should combine high grid resolution with techniques that decrease subgrid variability” An example of a technique would be useful here.

Authors: Following the reviewer suggestion an example of a technique used to take into account the subgrid variability is mentioned in the abstract:

*“Future work should combine high grid resolution with techniques that decrease subgrid variability (e.g., stochastic fields methods). [...]”*

Reviewer: P2, L12: replace “its” by “air pollution”

Authors: Following the reviewer suggestion, the sentence has been rewritten as follows:

From:

*“Air pollution legislation for the protection of the increasing city population has recently increased the demand for urban air pollution forecasting systems that can assess and understand its dynamics, alert the population when health-related issues occur, and develop emission abatement plans (EEA, 2011).”*

To:

*“Air pollution legislation for the protection of the increasing city population has recently increased the demand for forecasting systems that can assess and understand air pollution dynamics, alert the population when health-related issues occur, and develop emission abatement plans (EEA, 2011).”*

Reviewer: P2, L19: This is a bit of a presumption. The model may actually contain mathematical calculation and assumptions that are based on coarser 12km grid spacing. Don't just assume that the model is inherently designed to run at fine scales.

Authors: In order to avoid presumption, we have removed the following statement:

*“and better mathematical characterization of physical and chemical processes”*

Reviewer: P5, L1: I think answer is a poor choice of word here. The performance of different grid resolution is going to be dependent on many things. It's probably better to just remove this sentence entirely, since it doesn't add anything to the discussion.

Authors: The suggestion has been amended, and we have removed the following sentence:

*“The previous work demonstrates there is not a single answer which explains the merits of high-resolution modeling for all applications”*

Reviewer: P5, L24: What does "pre-coastal" mean? I haven't heard that term before.

Authors: the pre-coastal mountain range is a typical term used in the description of the Catalan Mediterranean system which consists of a wide coastal geographical region made up of a double system of coastal mountain chains running parallel to the Mediterranean Sea coast in Catalonia: the Catalan Coastal range and the Catalan pre-coastal range, as well as the Catalan coastal depression located among those mountain ranges.

Reviewer: P6, L18: How do you know dust was transported during this period?

Authors: The high pressure system crossing the Iberian Peninsula in a SW-NE direction usually transport dust from Saharan desert (Escudero et al., 2005) into the Iberian Peninsula. Desert dust transport during 12-18 April is confirmed by the forecast of the BSC-DREAM8b model (<http://www.bsc.es/earth-sciences/mineral-dust-forecast-system/bsc-dream8b-forecast>) and reinforced by the near real time evaluation with AERONET stations and MODIS satellite.

Escudero, M., Castillo, S., Querol, X., Avila, A., Alarcón, M., Viana, M.M., Alastuey, A., Cuevas, E., Rodríguez, S., 2005. Wet and dry African dust episodes over Eastern Spain. J. Geophys. Res. 110, 4731-4746.

To clarify this fact, we have included a comment on that as follows:

*“[...] from 12-18 April there was a high pressure system crossing the Iberian Peninsula in a SW-NE direction, transporting dust from the Sahara Desert and increased temperatures of up to 25-28°C confirmed by the mineral dust forecasts of the BSC-DREAM8b model (<http://www.bsc.es/earth-sciences/mineral-dust-forecast-system/bsc-dream8b-forecast>).”*

Reviewer: P7, L9: What do you mean by "nesting of over IPA throughout"?

Authors: authors mean that the CALIOPE-AQFS simulations at 1 km over AND, BCN and MAD domains are done by means of a one-way nesting over the simulation at 4 km over the Iberian Peninsula. The sentence has been rewritten as follows:

From:

*"In the present work CALIOPE-AQFS runs at 1 km x 1 km over the AND, BCN and MAD domains, with nesting of over IP4 throughout."*

To:

*"In the present work CALIOPE-AQFS runs at 1 km x 1 km over the AND, BCN and MAD domains, with a nesting over the IP4 domain."*

Reviewer: P7, L16: I doubt the layers "steadily increase". Most likely the layers become thicker with height.

Authors: we agree with the reviewer that the depth of the layers becomes thicker with height. The sentence has been rewritten as follows:

From:

*"[...] the CMAQ vertical levels are obtained by collapsing from the 38 WRF levels to a total of 15 layers that steadily increase from the surface up to 50 hPa."*

To:

*"[...] the CMAQ vertical levels are obtained by collapsing from the 38 WRF levels to a total of 15 layers whose depth increases with height from the surface up to 50 hPa."*

Reviewer: P7, L23: What year USGS data did you use?

Authors: the meteorological modeling uses a description of the land used based on USGS data from the year 1993. This information has been included in the manuscript as follows:

*"The Noah land-surface model (NoahLSM), based on the U.S. Geological Survey's (USGS) land-use data from the year 1993, is used by default in the present WRF configuration."*

Reviewer: P7, L31: Why did you not use AERO6, the latest version of the aerosol module? Please justify why you used AERO5 and not AERO6.

Authors: we used the AERO5 module instead the AERO6 module for two reasons:

- 1- The computational cost and the size of the input and output files increase when using AERO6 module because of the increase of the number of species, specifically of aerosol components. These are critical issues when working with high resolutions in a forecast mode.

- 2- There are no specific emission profiles to speciate PM fine emission to new ion species in Spain.

However, based on the significant improvement of the science about the primary organic aerosol aging and the sulfur chemistry we will consider using the AERO6 module in future works.

*“Although not used here, future simulations will use the updated version of the aerosol module (AERO6) which includes significant improvement about the science on the primary organic aerosol aging and the sulfur chemistry.”*

Reviewer: P8, L18: What do you mean "in one CPU"? That doesn't seem to make sense to me.

Authors: The sentence has been rewritten as follows:

From:

*“For the April 2013 simulation, times add up to 2880 CPU hours/day, or 86400 CPU hours in one CPU (9.86 years)”*

To:

*“For the April 2013 simulation, times add up to 2880 CPU hours/day, or 86400 CPU hours on a single processor (9.86 years)”*

Reviewer: P9, L43: What is an "information threshold"?

Authors: According to the 2008/50/EC directive, “information threshold” shall mean a level beyond which there is a risk to human health from brief exposure for particularly sensitive sections of the population and for which immediate and appropriate information is necessary”. In the manuscript, the reader has been referred to the European Directive already.

Reviewer: P12, L12: I don't think this statement adds anything to the discussion. Just remove it.

Authors: Following the reviewer’s suggestion, the aforementioned statement has been removed.

Reviewer: P12, L22: What do you mean by "perceptual" variability? I don't think this is the word you want to use here.

Authors: “perceptual” has been replaced by “relative”

Reviewer: P12, L24: Why is this obvious? Although the emissions are created using the same process, they are still affected by changes in meteorology and chemistry between the different resolutions. Remove this statement. Also, you say that the correlation coefficient does not change significantly, but what constitutes a "significant change" in  $r$ ? You should provide the  $r$  values for the two simulations here.

Authors: In the case of  $\text{NO}_2$  (Table 2) the  $r$  between resolution (4 km vs. 1 km) does not change ( $r = 0.54$ ). We say that it is obvious because, although  $\text{NO}_x$  is affected by chemical transformation and advection/diffusion processes, the  $\text{NO}_2$  is a primary pollutant estimated using the same emission methodology and the temporal variability is the same at both resolutions. We have rewritten the sentence as follows:

From:

"The correlation coefficient does not significantly change, which is obvious because emissions at both resolutions are modeled using the same approach"

To:

"The  $r$  does not change between resolution ( $r = 0.54$ ) partially due to the fact that the  $\text{NO}_2$  is a primary pollutant and emissions at both resolutions are modeled using the same methodology."

Reviewer: P12, L26: These are assumptions and not facts. You need to qualify this statement by saying "in theory". You do not know for a fact that the emissions are better allocated, and that the "artificial dilution" is improved or that the chemistry is treated better. If fact, the chemistry may not be treated better, depending on the assumptions made in the model.

Authors: Following the reviewer's suggestion, to qualify this statement we have rewritten the sentence as follows:

*"The bias improvement at 1-km resolution is justified, because in theory the higher resolution leads to better emission allocation from point, linear or area sources, decreases the artificial dilution of emissions compared to the larger grid area and, due to the decrease of artificial dilution, it treats chemistry more properly near large emission sources"*

Reviewer: P13, L1: This isn't a very useful sentence. I know you're using it to setup the next discussion, but I think it could be worded better.

Authors: As this sentence is not very useful, it has been removed.

Reviewer: P13, L6: What is 75p? Was this defined elsewhere?

Authors: the 75p means the 75<sup>th</sup> percentile. It has been clarified in the manuscript.

Reviewer: P13, L12: I'm confused. These numbers suggest an INCREASE in bias, so a DECREASE in model performance.

Authors: The sentence in the manuscript is correct. As defined in Appendix A, the bias score in categorical statistical evaluation (Eq. A1) is not the same as in continuous statistics (Eq. A10). The categorical bias indicates whether the forecast fails by overestimating (false positive,  $B > 100\%$ ) or underestimating (correct negative,  $B < 100\%$ ) exceedances and its ideal value is 100%. In the case of the evaluation of the CALIOPE-AQFS to forecast exceedances of the Max 1h  $\text{NO}_2$  concentration when increasing resolution, results indicate that 1-km simulation show the same tendency to missing exceedances (underestimation of exceedances) as 4-km simulation. However, the resolution increase favors the increase of hits and reduces the number of misses, slightly increasing from 37% (4 km) to 40% (1 km).

In order to explain better the meaning of this categorical bias the reader is referred to the corresponding equation as follows:

From:

*"The best performance is found for Max 1h  $\text{NO}_2$ , where bias (B) improves from 37% (4 km) to 40% (1 km)."*

To:

*"The best performance is found for Max 1h  $\text{NO}_2$ , where categorical bias (B, Eq. A10) improves from 37% (4 km) to 40% (1 km), although the tendency to underestimating exceedances remain with the resolution increase ( $B < 100\%$ )."*

Reviewer: P13, L20: This is actually a pretty interesting result. Why is there such a significant effect on the Max 1h  $\text{O}_3$  POD and CSI, but not on the Max 8h  $\text{O}_3$  and Mean 24h PM10. It would seem that perhaps the increase in resolution is changing the timing of the  $\text{O}_3$  max during the day. Is that the case? It would be nice to have a little more discussion here.

Authors: In the case of Max 1h  $\text{O}_3$  and Max 8h  $\text{O}_3$ , we do not think that changes in POD and CSI is influenced significantly by a timing change because the  $r$  on an hourly basis does not change ( $r = 0.61$ , Table 2) meaning that the temporal variability between resolution does not change.

Reviewer: P14, L1: instead of saying "opposite effect", just present the changes.

Authors: We agree with the reviewer, and we have presented the changes as follows:

From:

*"The resolution increase has the opposite effect on  $\text{O}_3$  over b and c for both Max 1h and Max 8h."*

To:

*“The resolution increase has the opposite effect on  $O_3$ , decreasing the number of hits by 14% for Max 1h and 33% for Max 8h. The increase of the number of correct negatives is less than 2% in both Max 1h and Max 8h  $O_3$ .”*

Reviewer: P14, L6: The subscripts for inorganic aerosols.

Authors: The subscripts for inorganic aerosols have been rewritten as follows:

*“sulfate ( $SO_4 = SO_4^{2-}$ ), nitrate ( $NO_3 = NO_3^-$ ), ammonium ( $NH_4 = NH_4^+$ )”*

Reviewer: P14, L20: Yes, the total mass of DD may be the same throughout the entire domain, but the concentrations should still change due to changes in meteorology between the two resolutions. It would suffice to say that DD does not change between the two simulations, assuming that really is the case.

Authors: The DD comes from the BSC-DREAM8bv2 model and is transported by the meteorological driver within the BSC-DREAMbv2. After that, it is added to the CMAQ output in a post-process on an hourly basis. In this sense, we considered that this sentence should remain in order to highlight that the only difference on modelling DD concentration between resolutions (4 km vs. 1km) is the interpolation from the resolution of BSC-DREAM8bv2 ( $0.5^\circ \times 0.5^\circ$ ) till 4 km and 1 km, accordingly, using a mass conservative method.

To clarify how desert dust contribution is taken into account within the CALIOPE-AQFS, the reader is referred to P8-L1-7:

*“CALIOPE-AQFS considers desert dust contribution by means of the BSC-DREAM8bv2, which runs off-line at a  $0.5^\circ \times 0.5^\circ$  resolution covering Europe, North Africa and the Middle East. Its outputs are mass conservative interpolated to the CMAQ’s Lambert conformal conic grids and at the required resolution and domain. After interpolating, the modeled PM10 concentration is: the sum of Aitken, accumulation and coarse-mode modes from CMAQ, and the corresponding BSC-DREAM8bv2 bins with a diameter of  $\leq 10 \mu m$  (Pay et al., 2012a).”*

Reviewer: P14, L23-26: Subscript

Authors: Acronyms for  $NO_3$ ,  $SO_4$  and  $NH_4$  have previously defined following the reviewer’s suggestion.

Reviewer: P15, L3-5: This doesn't seem to make sense. Above you state that the resolution increase results in a decrease in SS of 16%. However, here you're saying that when resolution increases the wind speed also increases. Increased wind speed should result in increased SS emissions. Is there a change in RH that is causing the decrease (unlikely). Please explain.

Authors: We agree with the reviewer. There was a mistake in the main manuscript, the wind speed decreases when the resolution increases from 4 km to 1 km. Figure 1 shows time series of the modeled U10 over 141 stations in the three domains (AND, BCN and MAD) as a function of the resolution: 4 km (red) and 1 km (blue). When increasing resolution the U10 decreases by  $1.4 \text{ ms}^{-1}$  in AND,  $0.4 \text{ ms}^{-1}$  in BCN, and  $0.2 \text{ ms}^{-1}$  in MAD.

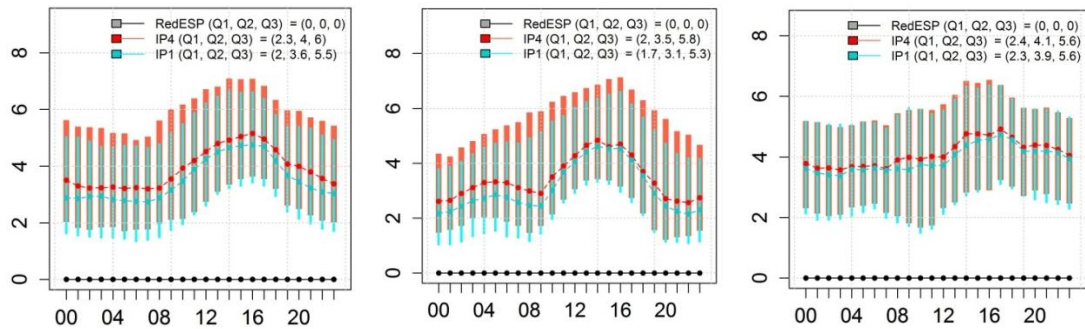


Figure 1. Wind speed at 10 m in AND (left panel), BCN (central panel), and MAD (right panel) over 141 stations at 4 km resolution (red) and at 1 km resolution (blue) modelled with the CALIOPE-AQFS for April 2013.

The statement has been written as follows:

From:

*“[...] when the resolution increases, the wind speed increases at the available PM10 stations by  $\sim 1.4/0.4/0.2$  ms<sup>-1</sup> over AND/BCN/ MAD, and also over the open ocean”*

To:

*“[...] when the resolution increases, the wind speed decreases at the available PM10 stations by  $\sim 1.4/0.4/0.2$  ms<sup>-1</sup> over AND/BCN/ MAD, and also over the open ocean”*

Reviewer: P15, L7-9: This isn't a very useful statement. It doesn't really say much about NO2. And why is NO2 being discussed here?

Authors: NO<sub>2</sub> is discussed here because it is a primary pollutant as EC and PPM.

Reviewer: P15, L16: What does this value represent? It's not at all clear.

Authors: It is the absolute difference between PM10 bias at 4-km resolution and bias at 1-km resolution, as shown in Figure 7. It has been clarified in the text as follows:

From:

*“MB decreases for PM10 ( $< 1 \mu\text{g m}^{-3}$ )”*

To:

*“MB decreases for PM10 (bias differences  $< 1 \mu\text{g m}^{-3}$ )”*

Reviewer: P15, L21: I don't think this the word you want to use here.

Authors: This concept of the “lamination of the PBL growth by the Mediterranean sea breeze” makes reference to the entrance of the on-shore flow that leads to a reduced mixing height (Perez et al., 2004; Millan et al. 1997). Millán et al. (1997) have already documented the first



rapid rise of the mixing height during the morning followed by the sinking of its capping inversion during the afternoon in the Mediterranean coastal area. Sicard et al. (2006) and Perez et al. (2004) also measured this phenomenon in Barcelona area using LIDAR.

Millán, M., Salvador, R., Mantilla, E., and Kallos, G.: Photooxidant dynamics in the Mediterranean basin in summer: results from European research projects, *J. Geophys. Res.*, 102, 8811– 8823, 1997.

Reviewer: P15, L30: This is a pretty broad time period.

Authors: We agree. The statement has been rewritten as follows:

From:

*“Both resolutions show the highest underestimations for the morning peak (5-9 am) (~20  $\mu\text{g m}^{-3}$ )”*

To:

*“Both resolutions show the highest underestimations at the morning peak (6 am) (~20  $\mu\text{g m}^{-3}$ )”*

Reviewer: P16, L6: How much is this on a percentage basis?

Authors: It corresponds to 21%. The sentence has been rewritten as follows:

From:

*“Increasing the resolution increases  $\text{NO}_2$  concentrations from 14  $\mu\text{g m}^{-3}$  (4 km) to 17  $\mu\text{g m}^{-3}$  (1 km) during the morning hours after sunrise (5-9 am) and in the evening hours after sunset (5-9 pm).”*

To:

*“Increasing the resolution increases  $\text{NO}_2$  concentrations by 21% from 14  $\mu\text{g m}^{-3}$  (4 km) to 17  $\mu\text{g m}^{-3}$  (1 km) during the morning hours after sunrise (5-9 am) and in the evening hours after sunset (5-9 pm).”*

Reviewer: P16, L23: Can you provide an example or two?

Authors: Missing sources are for instance the fugitive emission of agricultural activities and wind-blown dust. This comment has been introduced in the manuscript as follows:

*“The higher daytime underestimation as compared to the nighttime cannot be explained by the current results, but it could be a result of missing sources (e.g., fugitive agricultural emissions and wind-blown dust) [...].”*

Reviewer: P16, L29: What do you mean "allows improving"? I assume you just want to say "improves". It would be most useful to say increases or decreases, depending on what the case is.

Authors: We agree with the reviewer and “allows improving” has been replaced by “improves”.

Reviewer: P17, L2: Is this really going from negative 3.5 to positive 2.0? Just making sure that is correct.

Authors: The reviewer is right. There is a problem with the negative value. The sentence is rewritten as follows:

From:

*“The resolution increase reduces the bias from -3.5 to 2  $\mu\text{gm}^{-3}$  (by 43%)”*

To:

*“The resolution increase reduces the bias from -3.5 to -2  $\mu\text{gm}^{-3}$  (by 43%)”*

Reviewer: P17, L10: How are you so sure that improved performance in T and WS are responsible for the improvement in NO<sub>2</sub>?

Authors: We agree with the reviewer, we are not totally sure that the improvement on meteorology is the only fact that contribution to improve the performance of NO<sub>2</sub> concentration when increasing resolution. We have rewritten the sentence as follows:

From:

*“When the resolution is increased, NO<sub>2</sub> performs better because of the improved model performance for the temperature and wind speed (Sect. S1) [...]”*

To:

*“When the resolution is increased, NO<sub>2</sub> performs better partially due to the improved model performance for the temperature and wind speed (Sect. S1) [...]”*

Reviewer: P17, L16: What do you mean by "mean and variability"? This is awkward statement.

Authors: We agree that the statement is awkward. We have rewritten it as follows:

From:

*“Note that, in terms of mean and variability resulting from southeastern winds, the model performs well at the afternoon peak.”*

To:

*“Note that, in terms of temporal variability of the NO<sub>2</sub> concentrations the model performs well at the afternoon peak when air flow is controlled by southeastern winds.”*

Reviewer: P17, L16: What do you mean by "positive effect"? Do you mean a reduction in bias/error. If so, just say that.

Authors: The increasing resolution has a positive effect for NO<sub>2</sub> and PM10 in terms of correlation (increased by 0.01) and bias and error (reduced by 0.1-0.2 μgm<sup>-3</sup>). To clarify this statement, the sentence has been rewritten as follows:

From:

*"Increasing resolution shows a positive effect for NO<sub>2</sub>, and PM10 increases r by 0.01 and reduces MB and RMSE by 0.1-0.2 μgm<sup>-3</sup>."*

To:

*"Increasing resolution shows a positive effect for NO<sub>2</sub> and PM10 because it increases r by 0.01 and reduces MB and RMSE by 0.1-0.2 μgm<sup>-3</sup>."*

Reviewer: P18, L12: Why is this so obvious? I don't think it really is. Can you show that the differences are due to the limitations of the NoahLSM? If not, you need to say "may be because"

Authors: We agree with the reviewer, "obviously" is not the correct word. We have rewritten the sentence as follows:

From:

*"The low improvement at urban stations is obviously because the NoahLSM land-surface model does not consider the effect of urban morphology or thermal parameters in order to accurately model meteorological fields."*

To:

*"The low improvement at urban stations may be because the NoahLSM land-surface model does not consider the effect of urban morphology or thermal parameters in order to accurately model meteorological fields."*

Reviewer: P18, L20: Instead of just saying "positive", you should be specific here.

Authors: We agree. "positive" has been replaced by a number. However, the results indicate that the r improvement is less than the 2%. The sentence has been rewritten as follows:

From:

*"The impact on r of increasing resolution is positive for primary pollutants [...]"*

To:

*"The impact on r of increasing resolution is less than 2% for primary pollutants [...]"*

Reviewer: P19, L43: Performance of what?

Authors: the performance of the model. It has been include in the manuscript as follows:

*“Such behavior indicates that finer resolution improves the model performance”*

Reviewer: P19, L19: What does this mean? I think this sentence needs to be reworded. It doesn't make sense as written.

Authors: The following sentence has been removed because it does not contribute a lot:

*“However, the loss of subgrid variability and improved meteorological fields (transport and temperature) are required”*

Reviewer: P20, L16: What do you mean by "at large sources"?

Authors: We mean large emission sources. We have replaced “large source” by “large emission sources”.

Reviewer: P20, L27: What do you mean by "low increment"?

Authors: We mean “low gradient”. It has been amended in the manuscript.

Reviewer: P21, L5: This is an assumption. It's unlikely that increasing the resolution always improves the representation of fine-scale meteorology. You need to qualify this statement and make it less affirmative.

Authors: We agree. We have rewritten the sentence as follows:

From:

*“The benefits of increasing the resolution to 1 km over rural areas (Mass et al., 2002) are that it increases the accurate representation of mesoscale meteorological structures such as orographic wind and circulation.”*

To:

*“Increasing the resolution to 1 km over rural areas (Mass et al., 2002) could contribute to improve the representation of mesoscale meteorological structures such as orographic wind and circulation.”*

Reviewer: P21, L5: These references should come at the end of the statement, not here.

Authors: we agree. They have been moved at the end of the statement.

Reviewer: P21, L6: What do you mean by "urbanization steps"?

Authors: “Urbanization steps” makes reference to models that consider the urban morphology and thermal parameters. As this term is not self-explaining, the sentence has been rewritten as follows:

From:

*“Over urban areas along the western Mediterranean coast, further improvements and urbanization steps are required before seeing any benefits in increasing the resolution to 1 km [...]”*

To:

*“Over urban areas along the western Mediterranean coast, further improvements (e.g., models that consider the urban morphology and thermal parameters) are required before seeing any benefits in increasing the resolution to 1 km [...]”*

Reviewer: P21, L14: Again, this is bold assumption. You need to say that in theory, higher resolution should result in better spatial allocation of point and line emissions.

Authors: Following the reviewer’s suggestion the sentence has been rewritten as follows:

From:

*“The concentration increase in primary anthropogenic pollutants (NO<sub>2</sub>, PPM and EC) is obvious because the high resolution allows better allocation of emissions at point, linear and area sources”*

To:

*“The concentration increases in primary anthropogenic pollutants (NO<sub>2</sub>, PPM and EC) because the high resolution may better allocate emissions at point, linear and area sources”*

Reviewer: P21, L14: I think you're trying to say that even given the reasons above, move to 1km horizontal resolution generally did not result in better performance for O<sub>3</sub> and NO<sub>2</sub>. Is that correct?

Authors: Yes, it is correct. I have rephrased the sentence as follows:

From:

*“However, the 1-km simulation attempts to more accurately describe the chemical formation of O<sub>3</sub> and dilution of NO<sub>2</sub> concentrations over those areas was not generally successful”*

To:

*“Despite the reasons above, moving to 1-km horizontal resolution generally did not result in better performance for O<sub>3</sub> and NO<sub>2</sub>”*

Reviewer: P21, L14: You don't analyze the subgrid air quality in the paper. You're making an assumption here. More work clearly needs to be on fine-scale modeling. This work is only a single demonstration of fine-scale air quality modeling. Subgrid variability is always going to be an issue, regardless of resolution.

Authors: We agree that we do not analyze specifically the subgrid air quality in the paper, but it is an issue that is present in Eulerian models because of its formulation. We have rephrased the statement as follows:

From:

*“This analysis demonstrates weaknesses in the current model formulations that cannot be resolved with only high-resolution modeling. The subgrid air quality variability at 1-km resolution is not reproduced over large emission sources or urban areas, because a finer spatial structure is expected but unresolved.”*

To:

*“This analysis demonstrates weaknesses in the current model formulations that cannot be resolved with only high-resolution modeling. The subgrid air quality variability at 1-km resolution could be not reproduced over large emission sources or urban areas because a finer spatial structure is expected but unresolved.”*