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Comment on acp-2021-536

Anonymous Referee #2

Referee comment on "Quantifying urban, industrial, and background changes in NO₂ during the COVID-19 lockdown period based on TROPOMI satellite observations" by Vitali Fioletov et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-536-RC3>, 2021

This paper by Fioletov et al. is quantifying urban, industrial and background changes in NO₂ during the COVID-19 lockdown in Spring 2020 based on TROPOMI NO₂ tropospheric vertical column density data (VCD). A statistical regression analysis is used to separate urban, industrial and background components of the observed tropospheric NO₂ VCD. The total NO₂ mass of the three components is estimated and converted to emissions assuming a constant lifetime. The analysis was done for 263 urban areas around the world with a focus on urban areas from the US and Canada. To study the impact of the Covid-19 lockdown on the different components the analysis is done for the lockdown period in spring 2020 and is compared with the average of the same period in 2018 and 2019. It was found that changes in the background component are rather negligible but that the urban component declined over most regions by 18%-28% and for some regions even up to 60%. The decline in the industrial component varies more between the regions and declines up to 40% were found.

The study showed a new method to distinguish background NO₂ and NO₂ from urban and industrial sources by fitting of satellite data by a statistical model with empirical plume dispersion functions using wind data, data about population density, location of industrial sources and elevation data.

The paper is of significance for identifying and separating different components of NO₂ pollution and quantifying the impact of the COVID-19 lockdown on the different components. On the one hand, the paper and the appendix are already very long, and the authors should think about where they can shorten or compress (concentration on certain regions, leaving out the analysis with night light data etc.). On the other hand, the evaluation, comparison, and discussion of the results is too short in several sections, and this should be given more emphasis. There is also a lack of error consideration in the graphs and text. The chapter on the relative contribution of the different components needs further explanation and discussion on the representativeness of the results and the chosen area size. Due to the significance, the actuality of the topic and the new method for isolating various components of NO₂ pollution from satellite data, I recommend publication in ACP with major revisions.

General comments:

Can you comment on how much your study results are influenced by meteorology (wind, temperature, sun, clouds)?

More numbers and error estimations are needed and should be added to the figures and values in the text.

More comparisons to existing publications, especially to discuss declines of NO₂ found with your method, are needed.

Chapter 4.2 Relative contribution of different components (Page 12 Line 8/24):

The values you are giving ("urban and industrial sources are only responsible for a quarter of the NO₂", ...) are not really representative, they are largely depending on the size of your area. I have not seen a clear argument for choosing an area of 3°x4°. The results depend on size of the chosen area and size of the cities. If the areas are chosen smaller or in relation to the city size the contribution of background to the NO₂ mass would be reduced. Comparisons between 2020 and 2018/2019 are reasonable, but general statements about the relative contributions of the different components are difficult. Wouldn't it be possible to do the analysis without area size playing a role? If this is not the case, it should be better explained and discussed how the calculation was performed.

All references to the appendix should be consistent and clear, sometimes they are not. (P 3, L 22; P 6, L 24; P11, L31, and more)

Specific comments:

Page 3 Line 32: Specify the TROPOMI NO₂ product. OFFL or NRTI and which versions?

Page 3 Line 11: Can you better explain where these remote areas with background NO₂ are located?

Page 3 Line 24. Comment somewhere in this chapter on how the different data sets were brought together in terms of spatial and temporal resolution.

Page 4 Line 17: I think wind profile data are not directly available from ERA5, you probably computed them, a brief comment on that would be helpful.

Page 4 Line 22: It would be clearer if each dataset gets its own small chapter, since quite a lot is written about the individual datasets.

Page 7 Line 18: That sounds very general, perhaps just misleadingly formulated. Is the emission per capita factor coupled with the population density data?

Page 7 Line 48: "high population density zones typically occupy a small part of the area and industrial sources are typically located away from such highly populated zones" Not in general, for example in the Ruhr area in Germany, the Po valley or Riyadh this is not the case.

Page 9 Line 13: "We monitored the correlation coefficients between industrial and population density-related plume functions and, in some cases, excluded certain sources or even certain urban areas from the analysis." How was decided which areas were excluded, with a certain correlation coefficient?

Page 10 Line 12: Explanation for (g) is missing.

Page 10 Line 16: This explanation would have provided a better understanding about the used algorithm a bit earlier in the text, maybe include something similar in chapter 3 (The Emission fitting algorithm).

Page 10 Line 26: Why do you only give a value for one city (Boston) and not for the others? Please also add values for the other discussed cities. In addition, error estimation is needed and should be added to the figures and values in the text

Page 11 Line 5: Are the values comparable to results from other studies? For Boston but also interesting for the other cities.

Page 11 Line 5/6: Error margins are missing, please discuss and add to the figures and in the text.

Page 11 Line 10: Is the airport visible on the map, where is it located, please add a description in the text.

Page 11 Line 26. Why are oil refineries not included in the EPA NEI inventory, please comment.

Page 11 Line 31: Please include how additional sources not included in the inventories were discovered and added for the analysis.

Page 12 Line 1: I think this is true for some of the cities. At least for Seattle, the changes are not large, but for some of the other cities, changes in background values (especially Boston) and structure (especially Houston) are visible. Is this really negligible compared to changes in mean VCDs? Where do these changes come from?

Page 12 Line 12: Rephrase sentence, right now just the two facts (sharp gradients and short lifespan) are mentioned, make a better connection.

Page 12 Line 21: Add a reference here.

Page 13 Line 5: Did you calculate the average over the deviation of the background values of 2020 compared to 2018/2019? Yes on average not much happened between 2020 and 2018/19, but there are cities with a decrease and some with an increase, that should be mentioned.

Page 13 Line 18. If you think that these error bars also apply to the other areas, then they are maybe nearly all within the range of natural variability. How can you exclude that the weather in 2020 was not different from 2018/2019 for also other areas than Vancouver just in the other way?

Page 13 Line 27: Could it also be the different strength or length of the lockdown?

Page 14 Line 1: "Note that 2020 US EPA NEI reported emission were incomplete at the time of this study." What does that mean, how does it influence your comparison?

Page 14 Line 13: "The NO₂ decline was particularly large, more than 50%," The decline of only the urban or industrial component or in the mean?

Page 15 Line 2: What is about the strong increase for Sofia in the industrial component? In the urban component there is a strong decline. Any ideas about the different behavior

of the two components?

Page 15 Line 8/11: Please give standard deviation.

Page 15 Line 30: Is this induced by COVID-19 or by environmental policy decisions or weather?

Page 16 Line 7: What are the consequences for your method? Is the consequence that you cannot use your method for this case, how have you decided which cities are still good enough, have enough NO₂?

Page 16 Line 10. "Another obstacle is in Western Africa, where biomass burning made it difficult to estimate "background" levels as they were very different from year to year." How do you handle this problem? Are such cases excluded and according to what criteria?

Page 16 Line 28: It comes to mind that this might not just be background, but that background and urban/industrial components cannot be perfectly separated. Add one or two sentences of discussion.

Page 17 Line 18: "China shows the smallest and not significant decline in the urban component," Add that for China the strongest lockdown was before your chosen time window.

Page 18 Line 7: Why now back to the uncertainties in Figure 14? Add this earlier in the text before Figure 15 was discussed in detail.

Page 18 Line 23: Add which time periods are analyzed and compared for the mobility data. Same periods as before, so the 2020 period with 2018/2019?

Page 19 Line 3: The Comparisons to Lange et al. doesn't fit in this chapter (4.5 The global COVID-19 lockdown impact).

Page 19 Line 20: Nice that it worked, but is there really a new benefit from it, think about to skip it or only mention at some point that it is also possible to use night light data.

Page 19 Line 28: "On a scale of several hundred km (as we analyzed 3° by 4° areas), most of the NO₂ mass is typically related to the background component." See general comment about the representativeness of this results.

Page 21 Line 8: Add information about wind data, emissions (EPA, NPRI), world powerplant database, elevation and population data.

Figure 8: Figure description is not fitting very well to the figure. Add error bars to the figures. Adjust the scaling of the y-axis according to the values for all plots, even if you consider the following plots, it can be adjusted. Make clearer that this are the three components background, urban and industrial, especially the title "mean NO₂" over the background component plot is misleading.

Figure 9: Add regression line etc. Are the TROPOMI-based estimated emissions the sum of industrial and urban emissions? Please add a comment to the figure description.

Figure 10a, b: Same as for Figure 8.

Figure 14: Same as for Figure 8 and 10.

Figure 16: What is meant by "pre-lockdown period", which periods are compared with the google mobility data?

Technical corrections:

Page 1 Line 18: Add that you used tropospheric NO₂ vertical column density.

Page 2 Line 22: "One common approach is based on a rotation of satellite NO₂ pixels around the source to align the wind data to a common direction,"
"to align the wind data to a common direction" is misleading, should it not better be something like "to align the NO₂ data with wind data to a common wind direction."

Page 6 line 23: delete "as"

Page 6 line 24: shows instead of show

Page 9 Line 13: Correct "density-relate signal" to "density-related"

Page 10 Line 19: Correct "x" with the correct sign (dot) for multiplication

Page 10 Line 27: Why starting with Boston, when it is not the first city in the figure? Could be changed in the text or in the figure.

Page 13 Line 10: Delete first per.

Page 15 Line 16: "over the mountains in valleys in the Milan area." Replace "in" with "and".

Page 18 Line 7: "uncertainty values" instead of "uncertainties values" and delete "the regions"

Page 18 Line 19,20: The two sentences are very similar. Add "(background, urban, and industrial)" to the first sentence and delete it in the second one.

Page 20 Line 8: "Abrupt changes and urban and industrial emissions" change "and" to "in".

Page 20 Line 15: "than in the boundary layer and a relatively small amounts of NO₂" delete "a".

Page 21 Line 5: "to complement and emissions improve available "bottom-up" inventories" delete "emissions"

Figure 2: "Panel (b) is the sum of panels (d), (e) and (f)." Shift it after the description of (f) so before "Emission point sources are..."

Why is the second source in (g) a grey and not a black dot, could be changes to make it consistent.

Figure 4: "(c) and well as individual components" replace "and" with "as"
Mention the highlighting of the airport in the text.

Figure 7: In the figure the label says "Population" in the text below it is called "urban",
make it consistent.
"The contribution from industrial sources and cities" could be also changed to "industrial
and urban sources"

Figure 13. Change legend title in the top figure from "Environs Component" to
"Background Component" to make it consistent.