Response to Reviewer Comments

The authors focus on the declines and peaks in NO2 pollution during the multiple lockdown phases in the New York metropolitan area and disentangle the contribution of anthropogenic emissions sources and role of meteorology. In general, I find this manuscript to be of interest for publication and appropriate for Atmospheric Chemistry and Physics. I have one main concern and several minor suggestions for improvement listed below that should be considered by the authors before publication.

The authors use total column NO2 in this study and a few references are made to tropospheric column NO2 throughout the manuscript. The authors can be specific about whether the "column NO2" refers to "total column NO2" or "tropospheric column NO2". I have pointed out a few instances below. Typically, studies use tropospheric column NO2 to relate to changes in NOx emissions. How do the values of total column NO2 compare to tropospheric column NO2 for New York metropolitan area? The authors should consider discussing why total column NO2 is used and the possible impacts on the results.

We thank the Reviewer for their comments; they have substantially improved our manuscript. We also thank the reviewer for finding this manuscript to be of interest for publication and appropriate for Atmospheric Chemistry and Physics. Below, we include our response to the Reviewer's comments.

Following the Reviewer's suggestion, we made changes throughout the document to be more specific about whether the "column NO_2" refers to "total column NO_2" or "tropospheric column NO_2". The Pandora direct-sun retrievals provide the total column amount of NO_2, and any retrievals of tropospheric column would have to be based on assumptions regarding the stratospheric contribution. TROPOMI NO_2 is reported as total (tropospheric + stratospheric) column NO_2 when we compare to Pandora results, for consistency and more direct comparisons. Since in polluted areas such as New York most of the NO_2 is from anthropogenic emissions, the stratospheric amount is relatively low, and not as highly variable (spatially or temporally), compared to the tropospheric NO_2 column amount. Any change in NOx emissions would manifest as a larger % change in tropospheric NO_2 amount than in total column NO_2 amount. As we mention in the revised manuscript, our estimates of total column NO_2 changes from TROPOMI (and Pandora) are, thus, smaller than our TROPOMI estimates of NOx changes during the same timeframe, because there is a background component to NO_2 (see lines 332-333).

Minor comments

Line 68 Population and area of New York metropolitan area?

Information is provided in the revised manuscript (lines 70 and 75).

Line 81-86 Do both these studies use total column NO2? Or tropospheric column NO2?

The sentence has been modified to clarify this. These studies only use tropospheric column NO_2.

Line 85 "0.4° radius". Also mention in kms to compare to 100km radius in previous sentence.

Revised. This area was a 0.4^o x 0.4^o box centered on New York City, which is approximately equivalent to a 0.2^o radius or approximately a 22 km radius of New York City.

Line 101 "4% yr^{-1} decrease …" is in tropospheric column NO2. How would the trend values be for total column NO2?

Due to the relatively small amount of NO_2 in the stratosphere compared to the troposphere in urban areas like NYC, the difference is not expected to be large. For example, assuming ~ 0.1 DU stratospheric column NO_2 (Geddes et al, 2018; https://doi.org/10.5194/amt-11-6271-2018) for an average of 0.62 DU $TCNO_2$ (i.e., annual average $TCNO_2$ in Manhattan and Queens), this would correspond to ~approx. 3.5%/yr decrease.

Line 106 "…highest national NO2 levels." The authors can give value of annual mean NO2 and compare to the recently updated WHO guidelines.

Herman et al (2018) refer here to the total column NO_2 from PSI#135, while WHO reports surface levels NO_2. Results from PSI#135, including seasonal means pre- and post-pandemic, are discussed in more detail in this manuscript (section 3).

Line 117 Here and everywhere else, the authors mention high-frequency observations from Pandora but do not provide any value.

This information is now provided in the revised manuscript (section 2.1). The temporal resolution for Pandora measurements was approximately 1 minute.

Line 131 Section heading can be changed to "Materials and Methods" as the subheadings also focus on the various datasets.

To be more inclusive of different aspects of the methodology used here, we used Methods as the subheadings (i.e., datasets, study sites, approach, algorithms).

Line 135 Last assessed date for the URL.

Done. We included this information (PGN, 135 https://www.pandonia-global-network.org/, accessed June 4 2021) on Line 135 of revised manuscript.

Line 169 Tropospheric columns of?

This was referring to O_3, NO_2, SO_2 and CH_2O. We revised to "retrievals of O_3, NO_2, SO_2 and CH_2O total columns and information on vertical profile".

Line 173 Filtering criteria such as TCNO2>0 can lead to a positive bias in the mean TCNO2. Is it possible to quantify how much data is removed because of this filtering criteria and if the positive bias is large?

$TCNO_2 < 0$ does not have a physical meaning, and in almost all cases corresponded to cases when the error in the measurements was high. Less than 1% of the data was removed due to this filter.

Line 187 The authors use total column NO2, but the retrieval steps are also given for tropospheric vertical column.

This is a good point by the reviewer. TROPOMI data is also reported as tropospheric column in this manuscript for direct comparison with previous studies. This was clarified in the revised manuscript.

Line 189-190 Would the version change have a significant impact on the results?

The change between v1.02 and v.1.03 is considered to be minor by algorithm developers. Erroneous data is better filtered using the qa_flag in version 1.03 as compared to version 1.02 resulting in "smoother" less pixelated long-term averages. Based on the Users' manual, we do not expect a significant bias due to this algorithm change.

Line 193 Here again, the authors mention about validation of "tropospheric columns".

This was clarified in the document.

Line 253 "(v) in March-April 2021" should be "March-May 2021", right?

Thank you for catching this, correction was made.

Line 266 URL or DOI for MTA data?

This information is provided now on Line 269 of revised manuscript (For MTA data (https://new.mta.info/coronavirus/ridership, accessed 4 June 2021).

Line 297 "Variability in TCNO2 also decreased…" except New Brunswick?

Thank you for catching this, correction was made.

Line 320 "Fig.5, right panel." "Middle and right panels" perhaps?

Good point, we revised to "Fig. 5" for brevity.

Line 324-326 This statement starts suddenly and the value for NO2 changes need to be given before explaining why they are lower compared to NOx changes.

To clarify, we revised this sentence: "The reason TROPOMI $TCNO_2$ changes (Fig. 2) are smaller than NOx changes during the coincident timeframe ($\Delta TCNO_2$: ~24% vs. ΔNOx: ~35%) is because there is a background component to NO_2". The value for NO_2 change is given in the parentheses.

Line 339-344 The authors can consider giving a brief description of how these changes in NOx emissions were obtained (either here or in section 2).

This paragraph was revised to address the reviewer's comment. In the revised manuscript we mention that "Applying these reported changes in activity to corresponding estimated NO_x contributions from different components of the mobility sector in New York City (EPA) results in an approx. 26% decrease in NO_x emissions."

Lines 484-492 Interesting result!

Thank you.

Table 1 The table caption can include details of the time. “Present” may be replaced by “05/2021” Additional footnotes can be used on the column of “Temporal range of data” to mention data unavailability. For example, data from PSI#135 not available for Jan-Mar 2020 is mentioned in Figure 4 and should also be mentioned in table 1. The value of stdev for PSI#56,#69 for Sept-Nov reads as “0.24x”. Check for typo. Lastly, are both the PSIs at Queens, New Brunswick and New Haven in operation for the time period stated and is the data from both of them used?

We made the changes following the reviewer’s suggestions. The two PSIs at the Queens, New Brunswick and New Haven locations operated during different time periods and data from both are included in our study. Time periods when data at the four locations was not available is shown in Figure 3 that provides the full time series of $TCNO_2$ measurements for all sensors.

Figure 1 Is there a way the different major pollutant emitters can be identified on the map? For example, by use of numbers with the circles and the numbers can be stated in the figure caption. This would aid the interpretation of the results on lines 419-424.

We revised the figure to be able to easily identify the major pollutant emitters on the map.

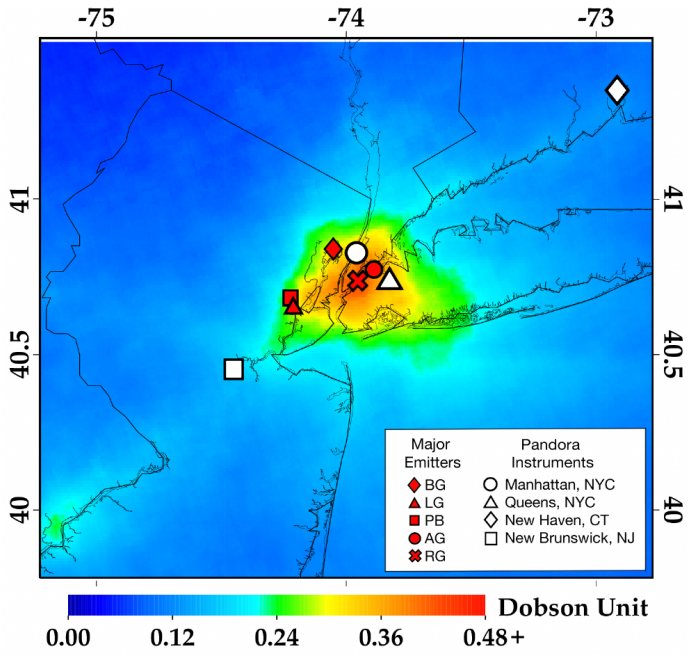

Figure 1: Map of study area, indicating location of Pandora sensors (white symbols) in Manhattan NY, Queens NY, New Brunswick NJ, and New Haven CT, overlaid with mean 2019 annual total column NO_2 from TROPOMI (in DU). Major pollutant emitters (red circles) in the area are included, specifically the PSEG Bergen Generating Station in Ridgefield (BG), the Linden Generating Station (LG) and the Phillips 66 Bayway (PB) Refinery in Linden (major emission sources in NJ), and the Astoria (AG) and Ravenswood Generating (RG) Stations in Queens, NY (among the largest greenhouse gas polluters in the state of NY in 2018 and 2019).

Figure 2 What is the “ratio difference”? It is not clear in the figure caption also.

This was changed to “ratio”.

Figure 7 The colors for TROPOMI and Pandora bars in (a) are different from the ones in the key. In panel (b), please add the year next to the months and consider adding error bars.

Done.

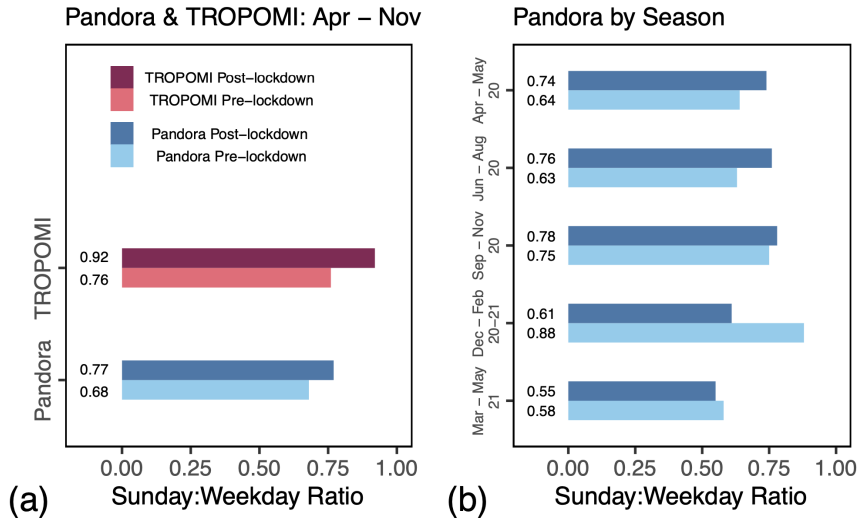

Figure 7: (a) Sunday-to-weekday $TCNO_2$ ratios averaged over Apr-Nov 2018–2019 (pre-lockdown) and 2020 (post-lockdown) from TROPOMI and Pandora (PSI#135); (b) Seasonal change in Sunday-to-weekday column ratios pre- and post-lockdown from Pandora (PSI#135).

Figure 8 The caption can be slightly modified to reflect that TROPOMI observations are only over Manhattan.

Done

Figure 9 The authors can consider labeling the panels and refer to the individual panel in the text.

Done

Figure 12 The time and location are missing in the figure caption.

These are showing averages between May 2018 and December 2019. This is applicable to both Figures 11 and 12. The figure captions were revised (Figs 11 and 12).