Response to reviewer 2

The Effects of the COVID-19 Lockdowns on the Composition of the
Troposphere as Seen by IAGOS
Clark *et al*
MS No.: acp-2021-479

Summary

The authors use ozone, CO and meteorological measurements from the IAGOS
dataset for Frankfurt airport to study the impact of COVID lockdowns on air quality.
They compare measurements during spring 2020 (European COVID lockdown) to
the previous 27 years of data (20 years for CO). They find surface level increases of
ozone during the lockdown period driven by increases in nighttime ozone. The
anomaly in ozone turns to a slight negative at higher altitudes.
The authors also find a reduction on CO at the surface and little to no reduction at
higher altitudes which they attribute to incoming emissions from outside Europe. This
hypothesis is strengthened by IASI CO retrievals of the same period.

General Comments

This is a decent study that fits well with other COVID air quality related publications.
It is useful to have the view of the free troposphere as most publications focus on
surface level impacts. The authors give a good overview of the current literature and
highlight what extra information this study can give. I feel the following comments
need to be addressed before publication.

As the ozone data for April 2020 is missing, is a comparison to the MAM climatology
valid? Do you remove April from the previous years to take the climatology and if not,
does it have an impact on the result?

>*We did not have ozone data for the month of April and April has been removed from the
climatology. The text and figure caption have been updated to make this clearer.*

I find the difference in time series and calculated climatology between ozone and CO
leads to an incoherent picture. I would recommend using the same baseline years
for both ozone and CO.

>*As suggested by the reviewer, we have re-done the analysis for ozone using the same 2016-
2019 baseline as for CO. This has only slightly changed the results, such that there is a
slightly stronger decrease in ozone seen in the free troposphere.*

A measure of statistical significance is needed on the presented results. Without this,
the arguments for why we are seeing the anomalies aren't as strong as they could
be. I am unsure if using the standard deviation as the definition for interannual
variability in this case is the best way to present the results. Would the range or a
percentile (e.g. 95th) be a more suitable parameter to use? If a month is one
standard deviation from the mean there is still ~30% chance it would be completely
expected. Showing if the lockdown period fell outside the 95th percentile for example
would really highlight if it was an unusual year.

>We have added confidence limits and the interannual variability to all of the individual monthly bar plots that we discuss calculated on the basis of Student's t test. It is now more apparent how significant the anomalies are, since the number profiles within each month is taken into account. The interannual variability over the 2016-2019 period is the standard deviation of the monthly means. Since for the reference period there are only 4 monthly means, the standard deviation seems to be a better choice than percentiles for measuring variability of a sample of size 4.

Some of the discussion points are mixed in with the results (e.g. the discussion about previous ozone events during heatwaves). This is ok to put the results into context but it leaves the final section of the paper more like a summary rather than a conclusion. I recommend moving some of these sections into the conclusion.

>As the reviewer points out, some of the discussion in the results section does help to put the results in context and guide the reader. As suggested we have moved some of the discussion on the 2003 heatwave to the conclusions section.

Section 2.2.2 discusses the drop in CO in the free troposphere and trying to relate that to the lockdowns but as far as I can see from figure 8 they were mostly well within the expected interannual variability. This doesn't appear to be mentioned and the results are presented in a way that suggests that the changes are abnormal. Clearly stating the anomalies are within the expected range is needed here.

>We have clarified in the text that there was no significant anomaly for CO in the free troposphere. This is made much clearer by the addition of the confidence limits on figure 14.

Specific & Technical Comments

There are a number of occasions where there are double negatives (e.g. -XX% drop). Either say XX% drop or -XX% change (or something similar).

>We have fixed these

Throughout: There are a number inconsistencies with spaces between numbers and units which need to be fixed.

>We have fixed these.

Line 23: The Le Quere paper only focuses on CO2, I would either add examples of AQ papers by for the atmospheric composition statement, or rewrite this sentence. OK,

>As suggested, we have added some example of the AQ articles.

Line 79 & 232: should be 'balloon-borne ozonesondes'

>Done

Line 80: I think this should be 'reduction in surface emissions' not 'pollution'

>*Done*

Figure 1 & 8: I suggest changing the y axis to hPa and mark where your free troposphere definitions begin/end. This way the reader can more easily see which bit of the profile you are discussing.

>*We have added horizontal lines to the profiles to highlight the sections discussed.*

Lines 156 & 157: Specify air traffic

>*Done*

Lines 156 – 159: is the 50% reduction in (air) traffic related to the the introduction of restriction measures (22nd March) or were there measures in place before this date that was reducing air traffic?

>*In the text we have added the following: This reduction was driven by a fall in passenger numbers as lockdown measures spread around the world.*

Line 212 & figure 5: 00:00-09:00/19:00-23:59 is confusing, I would either replace the slash with an ampersand or say '7 pm to 9 am'

>*Done*

Figure 4: What do the numbers on the secondary y-axis denote? >The secondary axis

denotes the counts for the period 2016-2019. We have added this explanation to the figure

caption.

Line 245: This should be 'inflection' not 'inflexion'

>*done*

Line 262: I would say 'As with ozone…' not 'As for ozone…'
>*done*

Line 291: airports *than* might be though

>*done*

Line 302/303: What do you mean you're ignoring fire or anthropogenic sources of CO? That doesn't leave much. Or do you mean you are not distinguishing between them and only looking at source regions? This needs to be clearer.

>*We are focussing on the geographical source regions of the airmasses in 2020 compared with the reference period but we can say a bit more about the fire sources of the CO. It should be noted that SOFT-IO does not calculate a background value for CO. It is adapted to analysing the origin of plumes that are well defined against the background. This is not our case here. We have quantified the absolute contribution from the biomass burning as requested by reviewer 1. However, because the anthropogenic emissions are not updated for the COVID period, we cannot give the relative contributions of biomass burning and anthropogenic emissions. Since the biomass burning contribution decreased in 2020, we expect a higher contribution from anthropogenic sources. We have added some discussion about this in the text related to line 302 and line 336 in the comment below.*

Line 305: there is reference to fig 13 before saying you're talking about figure 13.

>*We have corrected this.*