Response to the reviewer 1

The authors did an impressive work in collecting and analyzing activity data related to fossil fuel emissions during the COVID period. The results of this work can serve as a good reference in research related to the COVID impacts as well as atmospheric models. However, I believe that several issues could, and should, be further elaborated by the authors to help with the better understanding of this dataset.

We thank the reviewer for his/her interesting questions and comments. Please find below our answers.

1) line 109-112 says, "The collected data are then analyzed and an intercomparison of the changes in activity data from datasets providing similar or equivalent parameters are performed. The dataset that provides the most detailed and reliable data is then chosen."

This only applies to the transportation sector, correct? Because other sectors seem to suffer from lacking of data and the authors really didn't have much of a luxury to choose from different activity datasets for other sectors.

My question is, what is the standard for choosing the data in transportation sector? To be more specific, how did the authors define "reliable"?

The authors listed a comparison between the APPLE driving data and google mobility data. Figure S1 did show that APPLE data has more variations compared to google data. But does that mean APPLE data is less reliable? What is(are) the ultimate reason(s) for the discrepancies between APPLE data and google data? Besides the spatial coverage, what made the authors believe that google is more reliable than APPLE? Couldn't it be that in reality, the transportation emission IS that variant in different countries/regions?

For the road transport sector, we have indeed much more information than for the other sectors. For the industrial and aviation sectors (Figure S4 and S5, Supplementary material), two datasets were available. We are aware of the lack of up-to-date data on certain sectors of activity. This is why the manuscript indicates in lines 113-114: "an intercomparison of the changes in activity data of datasets providing similar or equivalent parameters is performed".

The use of the word "reliable" may not be the best word to use in this context. It has been replaced in the text by the term "which meets better our needs" (line 115). What we mean by our needs are the data that are publicly available for as many countries as possible, and where we can find information on a daily basis.

Our choice of Google instead of Apple related to the following analysis:

   - Google and Apple datasets do not measure the same mobility parameters: Apple bases their values on the volume of directions requests on phone applications while Google uses mobile phone locations. The comparison of these datasets indicates that the changes are similar when traffic is strongly reduced (March-May). However, from June to August, Apple data exhibit more variability compared to Google data, with a 2 to 3 times increase in mobility relative to the pre-covid period (Figure S4). These differences can be attributed to a combination of several factors including the spatial coverage, the mode and category of

2) Line 113-105, "The gridded daily/monthly files per sector are obtained by assigning the value of the AFs at the country/state/province level to each corresponding grid cell"
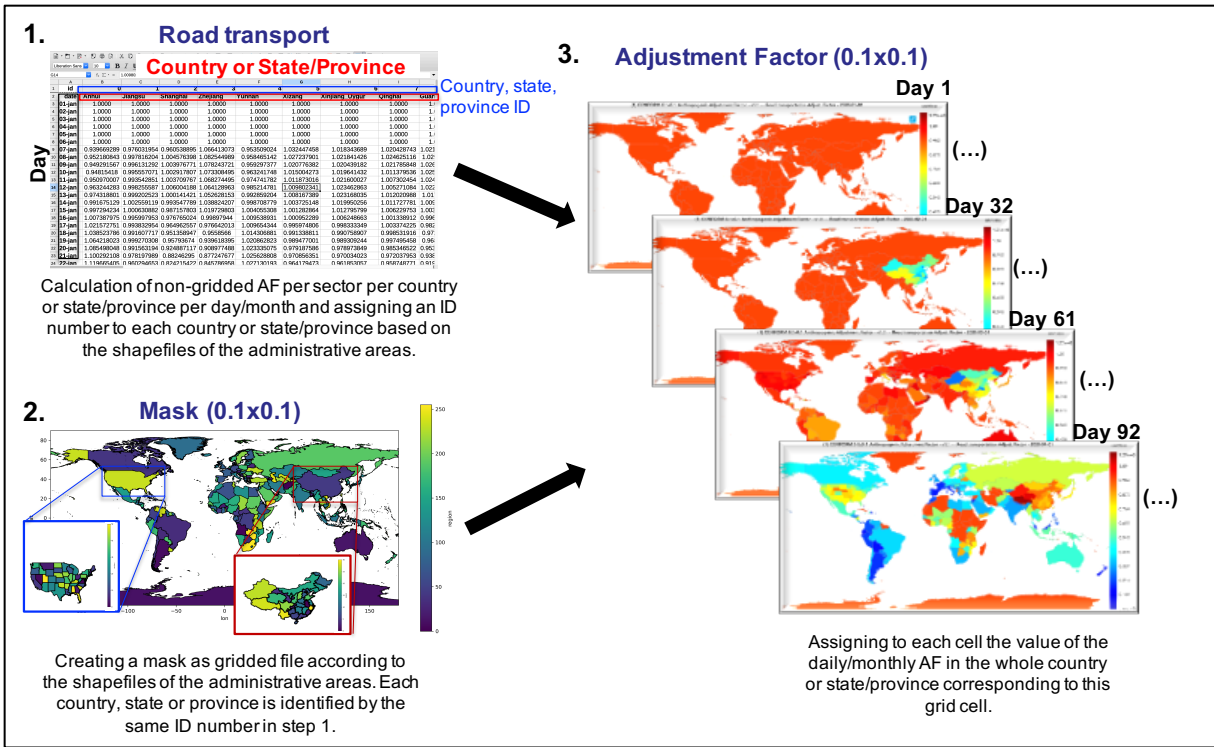
I have not found a detailed description on this in methodology. How exactly was the gridding implemented? The data sources listed in table 1 are mostly at national scale or province/state scale. How were they downscaled into 0.1 degree grids? What was used as the proxy? How reliable was the proxy?

1. Road transport
Country or State/Province

Country, state, province ID

Day

Calculation of non-gridded AF per sector per country or state/province per day/month and assigning an ID number to each country or state/province based on the shapefiles of the administrative areas.

2. Mask (0.1x0.1)

Creating a mask as gridded file according to the shapefiles of the administrative areas. Each country, state or province is identified by the same ID number in step 1.

3. Adjustment Factor (0.1x0.1)

Day 1
(...)
Day 32
(...)
Day 61
(...)
Day 92
(...)

Assigning to each cell the value of the daily/monthly AF in the whole country or state/province corresponding to this grid cell.

3) Line 144-147,"In order to make the calculated AFs comparable with those derived using the other data sources considered in this study, the AFs for the Google's categories are scaled as a function of the Google mobility data, so that their values are less than 1 for a reduction in activity and above 1 otherwise."

I'm confused here. What is the baseline for 1? The authors mentioned in previous text in line 137-138 that "This baseline is calculated as the median value over the five-week period from January 3rd to February 6th 2020." But that was the Google's definition of baseline for their mobility data, not the same baseline used to calculate AF in this paper, correct?

Or was it the same thing? Please clarify.

Also, is the baseline the same for all other sectors? Please clarify.

To make the text clearer, we have changed lines 154-157, and the new text is the following: "In order to make the calculated AFs comparable with those derived using the other data sources considered in this study, the AFs for the Google's categories are scaled to 1 using the following formula AF = 1+ Google/100, so that their values are less than 1 for a reduction in activity and above 1 otherwise."

We use the same baseline period as Google, except for China for which the lockdowns started earlier. We use the same baseline for the other sectors, except for those for which we only have monthly activity data. For those sectors, we consider the value of January as the baseline. These details have been included in the revised manuscript (Lines 130-138).

4) This is not a question but rather a comment. The "uncertainty" as showed in Figure 2,3,4,5,6 is not the result of validation based on other reliable datasets, but instead, it refers to the AF variations at different geographical locations. In my opinion, the authors should call it as what it is instead of insinuating that it could be something that it is not. I'm not saying the

authors didn't do data validation, they did, as shown in figure S4 and S5. But the light pink color in figure 2,3,4,5,6 is not the result of validation.

The light pink color on Figures 2 to 6 shows indeed the standard deviation resulting from the AFs of all individual countries or states/provinces, as indicated in the legend of each figure. The text (lines 330-332) has been modified as follows: "The regional variations of AFs (light pink color) are determined as the standard deviation from individual values of all the countries in the region or from local measurements in the country or state/province."

Response to the reviewer 2

General comments:
Doumbia et al. present an interesting and important dataset on changes in global air pollutant emissions during the COVID-19 pandemic focusing on adjustment factors (AFs). This dataset is not only useful for global and regional emission inventories development, but also for atmospheric chemistry modeling, which is worth publishing in ESSD. I have several concerns on this paper.

We would like to thank the reviewer for agreeing to review our paper and for his/her valuable comments. Please find below our answers.
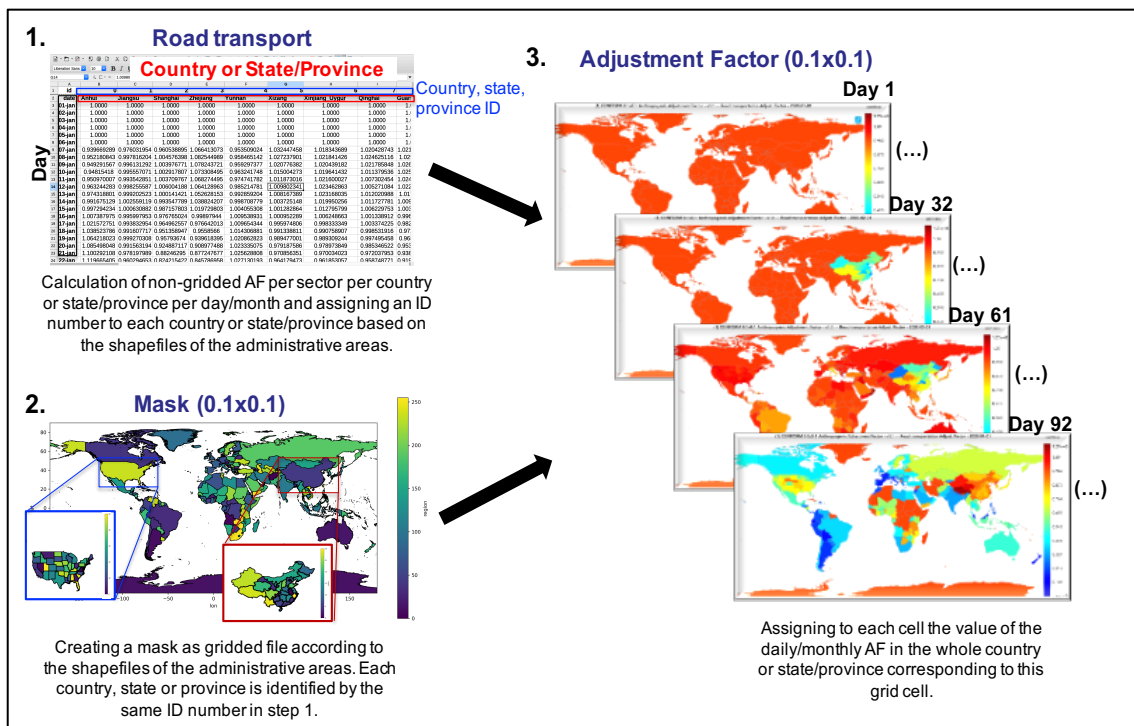
1. Concerning the spatial distribution, the Methodology does not provide enough details on how the 0.1x0.1 dataset was created, how to support the 0.1x0.1 resolution ? And the Results part showed only one spatial pattern figure (Fig. 8), which also need to be largely expanded not only for NOx.

This question is also addressed by the other reviewer, so our answer will also be included in the answers to the other reviewer.

In order to provide more details on the description of the methodology, we have rephrased lines 117-122, and the new text is:

"The gridded daily/monthly netcdf files developed for each sector are obtained by assigning, to each cell, the value of the AFs in the whole country or state/province level corresponding to this grid cell: this is based on the fact that the lockdowns and restrictions have been generally taken at national or state level. For several sectors (road transport, industry and residential) the AF at the country or state/province level represents an average value calculated from several individual cities or locations."

The figure below gives an illustration of the allocation of the AFs to each grid point at a 0.1x0.1 resolution in a country or a state/province.

Concerning your comment on the expansion of the spatial distribution to other species, we have added the following figure in the supplementary material (Figure S8), which shows the absolute changes in the total emissions of CO, NMVOCs, SO_2 and BC for April 2020.

Change in emission : April 2020 [kg/km²/month]
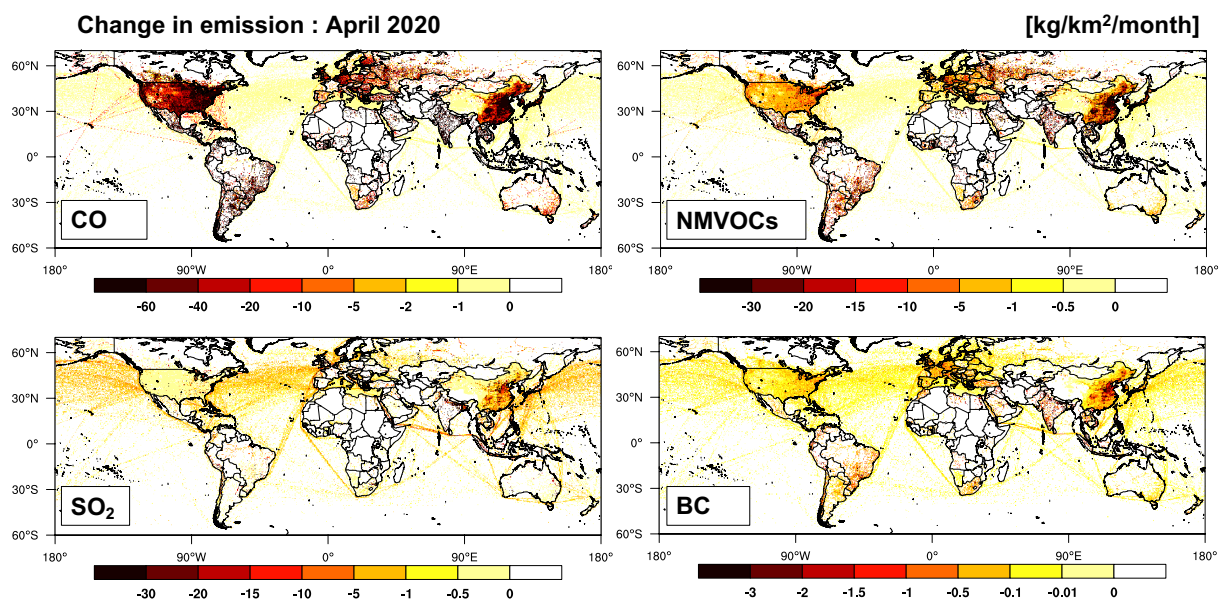
2. Since the COVID-19 pandemic is still severe and the confirmed cases are increasing (https://www.worldometers.info/coronavirus/), this important dataset can aim to update it continuously, not only to the end of 2020 (lines 92-93).

We are indeed considering an update of the dataset until the end of the pandemics. For example, for the air traffic sector, we have recently extended the AFs to December 2020, as

shown in the figure below. These data will be included in the database during March 2021. We are compiling the available activity data for the other sectors, for a further update in the coming months.

Air traffic sector - Global average
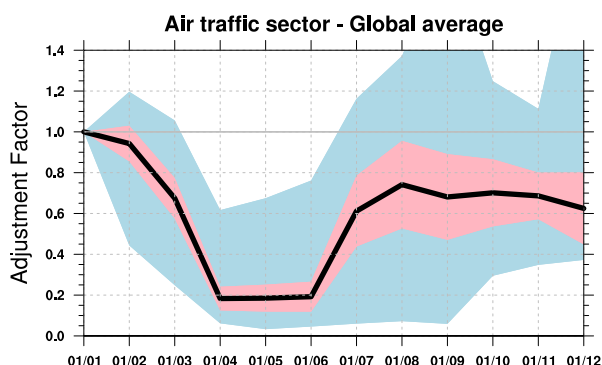
3. How the AFs are calculated for different pollutants is not so clear with specific equations, especially when there are multiple sources activity data (e.g. industrial processes);

In our study, the estimated AFs are provided on a sector, geographic and temporal basis, not on a species basis. The AFs are provided for the sectors commonly used in emission inventories, i.e. energy, industry, residential and transportation. They can therefore be applied to any inventory providing the emissions of atmospheric pollutants.

4. Why are there larger decreases (30-50 %) in South America than other areas (e.g. China, EU and US) for NOx, NMVOCs and CO. And Fig.8 seems to show that China has the largest decrease, rather than South America ?

The larger decreases in South America shown in Figure 7 (Figure 8 in the revised manuscript) result from very strict restrictions in many countries in Latin America. For example, in Argentina, a very strict lockdown was implemented on March 19, 2020 and was extended several times until the end of the summer 2020. Figure 8 in the first version of the manuscript showed the spatial distribution of the absolute change in the Covid-19 NOx emissions compared to the reference scenario (without Covid-19) in China during the month of February while for the rest of the world the considered month is April, the periods of strictest restrictions.
To make these results clearer, we have added two figures in the supplement, Figure S7 and Figure S8, which show the absolute changes in total emissions of CO, NMVOCs, SO_2 and BC for April 2020 and the percentage changes at the global scale for the first six months of 2020, respectively.
We have also added a new figure (Figure 9 in the revised manuscript) showing the distribution of the absolute and percentage changes in NOx emissions for the month of April 2020.

Some minor comments:

1.The title might be too limited for only "atmospheric chemistry modeling";

The title has been changed to "Changes in global air pollutant emissions during the COVID-19 pandemic: a dataset for atmospheric modeling".

2. Line 51 are repeated for CO with lines 48-49;

We have removed CO from the sentence.

3. Line 65 for greenhouse gas, there are other references (Han et al., 2021; Zheng et al., 2020);

These references have been included, in line 67 of the revised manuscript.

4. Line 81-82, need to expand the meanings of this dataset ? e.g. provide assessments on COVID-19 restrictions on pollutant emissions;

This remark is considered in the revised manuscript. The sentence, in line 82-85 of the revised manuscript is rewritten as follows: "The advantage of such a dataset, which provides adjustment factors for assessments of the impact of COVID-19 restrictions on pollutant emitted into the atmosphere, is that it can be applied directly to any global or regional inventory used in chemistry-climate and transport models in a flexible way".

5. Line 95, could CO_2 be included? It would be better for homology studies.

Though the AFs from the CONFORM dataset can be applied to the emissions of any species, we have only considered in section 3.5 its application to the emissions of the species indicated in line 98 of the revised manuscript.

6. Lines 116-117: Add some introduction on CAMS -GLOB-ANT;

We have provided the following information on the CAMS-GLOB-ANT dataset in section 3.5, lines 449-452: "This dataset (CAMS-GLOB-ANT) provides daily emissions of the main atmospheric compounds, including speciated volatile organic compounds at a 0.1°x0.1° resolution, from 2000 to 2020. Version R.1 of the CAMS-GLOB-ANT_v4.2 dataset incorporates the MEIC1.3 regional inventory for China described by Zheng et al. (2018)."

7. Lines 119-120 repeated with Lines 92-93;

Lines 119-120 have been removed.

8. Line 157: In reference to (Han et al., 2021), monthly road (and also ship) transportation data for China can be obtained at http://www.mot.gov.cn/tongjishuju/, but it needs some translation and digitalization work to obtain the data. And it is up to the authors to decide whether to include such data;

We thank the reviewer for providing this information. We might consider this dataset in another study, where we could compare our dataset obtained from Baidu (https://qianxi.baidu.com/) with this dataset.

9. Lines 197-198: Maybe need some discussions. The assumption is not very consistent with Liu et al., 2020, see (https://www.carbonmonitor.org.cn/user/data.php?by=cn);

Ground Transport
地面运输
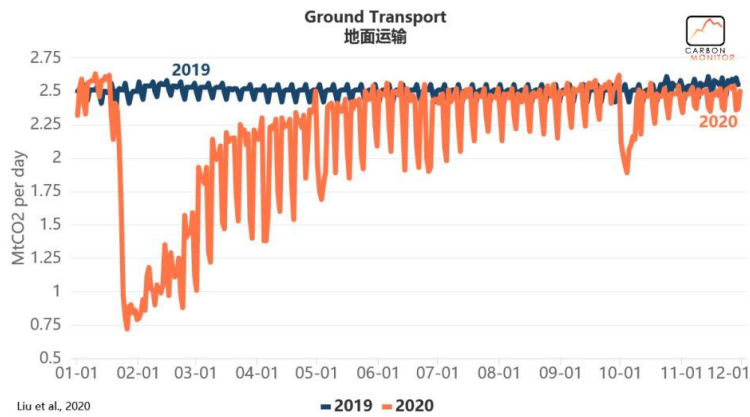
We thank the reviewer for provided this information from the carbon monitor website. The data proposed by the reviewer provide emissions of CO_2 for road transport in China from January to November: we retrieved the data and found an average difference between 2020 and 2019 of about 4% for the period from May to November, with larger values for some days (see figure below).
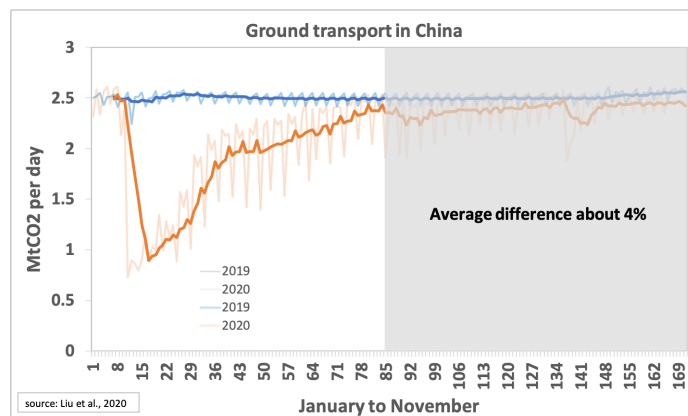
We compared the changes in the Baidu Migration Scale Index with the relative difference of TomTom congestion levels for the Beijing, Tianjin, Chongqing and Shanghai Chinese areas. TomTom archived data are not freely available, but they can be retrieved from published graphs (https://www.tomtom.com/en_gb/traffic-index/ranking) providing the weekly changes in 2020 relative to the same periods in 2019. The results show a strong similarity between changes given by these two datasets for the period covered by the Baidu dataset (January to April), with a correlation coefficient of 0.9 (Figure S3). For the period from May to August 2020, Liu et al. (2020) showed that the difference in estimated CO_2 emissions from road transport between 2020 and 2019 is on average about 4% for May-November, with larger values for some days. Based on these analyses, and in order to cover the whole period of our study (January to August), we assume that changes in road traffic in China after May 2020 are relatively low and close to those before the spread of the COVID-19 pandemic. These comparisons show that the proposed method for calculating the AFs (i.e. ratio between the activity data and the median value of activity data over a defined reference period) is consistent with changes in 2020 relative to the same period in 2019.

10. Lines 201-202: add a reference;

The link for accessing to the TomTom congestion data has been added to the revised manuscript (Line 211).

11. Line 205: May need to add time resolutions (e.g. daily or monthly) for sectors in Table 1;

The time resolutions for the different sectors considered in this dataset are now added in Table 1.

12. Line 211: Cement is not included in this dataset?

Cement is not explicitly included in our dataset. Industrial activities are considered as whole, using the Google's workplaces measurements.

The indication of cement was just an illustration of what could be considered in this sector as we defined it, since its definition can be different from one inventory to another. To avoid a confusion from the readers, we have rewritten the sentence as (lines 226-227):

"This sector includes industrial production processes such as manufactured products from fossil fuel combustion, and represents a significant part of the emission sources of atmospheric pollutants".

13. Line 216: For China monthly data, the iron, steel and cement production can be obtained at https://data.stats.gov.cn/english/easyquery.htm?cn=A01 in "Output of major industrial products"

We have already checked that the trend of steel production from China's national statistic is similar to those derived from the World steel as used in the paper. For the industrial sector, the AFs are estimated from Google's workplaces category. In China we assume that coal consumption from the six main coal producers is representative of changes over this sector. Monthly steel productions are therefore used only for evaluating the use of Google mobility instead of monthly national data (Figure S4, Supplementary information).

We thank the reviewer for proposing a site with data for China. However, the site indicated by the reviewer could not be reached by the co-authors working in Europe. We tried 3 different browsers on computers connected to the internet through 4 different providers, and the answer was always the same, i.e. "Warning – Potential Security Risk: a security threat was detected". After contacting the system administrators of our institutes, we were told that we should not try to connect to this site, and that we cannot refer to it in any paper.

14. For Section 2.3, China's power data can be reflected by daily coal consumption at six main power groups, see (Han et al., 2021) Fig.4, and the data is provided at the end of this file.

The AFs for the power sector in China was estimated based on emission data published by Forster et al., 2020. At the time we were writing the paper, this was the only data we could access to. However, the comparison between Forster et al., 2020 and Han et al., 2021 data shows rather similar AF trends as indicated in the figure below. As indicated above, the reference to Han et al. (2021) has been added to the manuscript.

Power in China
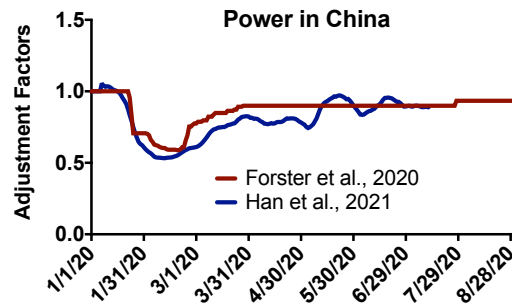
15. Lines 251-252: Can compare with data from International Civil Aviation

Organization (ICAO). I noticed a report which contained regional/country data (https://www.icao.int/sustainability/Documents/COVID-19/ICAO_Coronavirus_Econ_Impact.pdf), which you may find useful in cross validation;
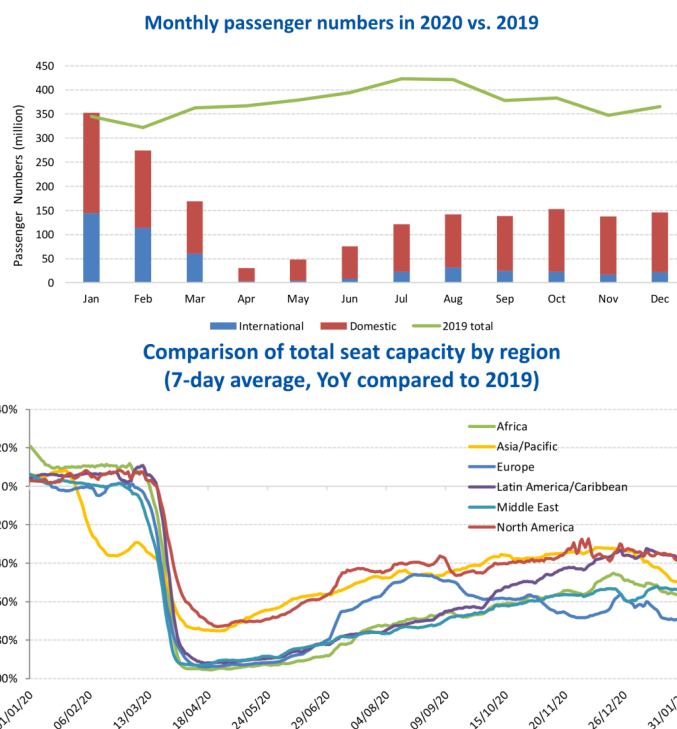
We have used the data from organizations provided the number of flights operating during the year 2020. The dataset recommended by the reviewer does not provide data as accurate as the ones we have used: ICAO provides the number of passengers carried in 2020, compared to 2019. However, as the number of passengers carried does not reflect the number of flights operating, we have preferred to use air traffic data, as the number of planes flying is a better indication of the emissions.

16. Line 324: Also consider these refs. (He et al., 2021 ; Sun et al., 2020; Zhang et al., 2021);

These references have now been included in the paper, in lines 339 and 340.

17. Lines 375-377: May be not this case (see below 3 figures), and CO2 emissions from Liu et al., (2020) (https://www.carbonmonitor.org.cn/user/data.php?by=cn) and NBS statistical

data on iron and steel and cement productions
(https://data.stats.gov.cn/english/easyquery.htm?cn=A01) showed that industry in China
recovered soon after April 1st, and surpassed the before COVID-19 mean state.
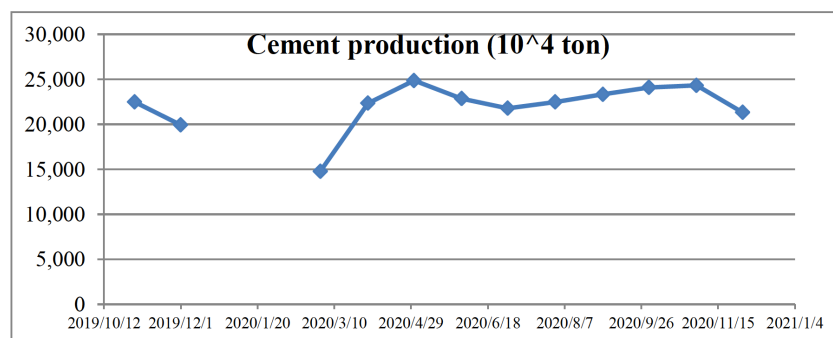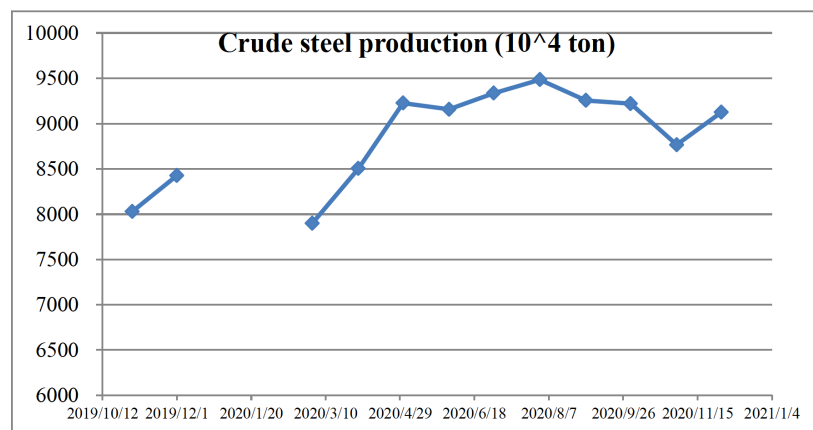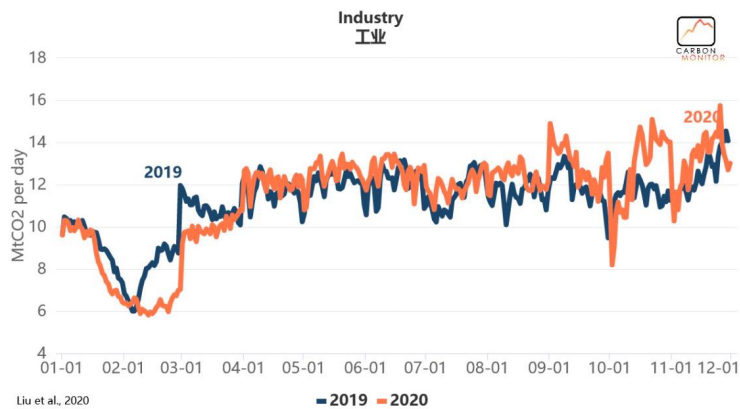
Thank you for this helpful information. For the industrial sector, we extracted the coal
consumption data for the six major firms in China from Myllyvirta 2020
(https://www.carbonbrief.org/analysis-coronavirus-has-temporarily-reduced-chinas-co2-
emissions-by-a-quarter). The comparison with data from Liu et al., 2020 shows clear
discrepancies from May to August. Note that, at the time we were retrieving the data from the
carbonbrief website, emissions were available only until May 2, 2020 and we extrapolated
them until August. This might explain the underestimation of the increase in the industrial
activity in China after April. In the revised manuscript, the AFs for such sector have been
updated using the data published by Liu et al., 2020 (see Figure below). The reference
provided by the reviewer is added in Table 1. We have updated Figure 4 as well as the
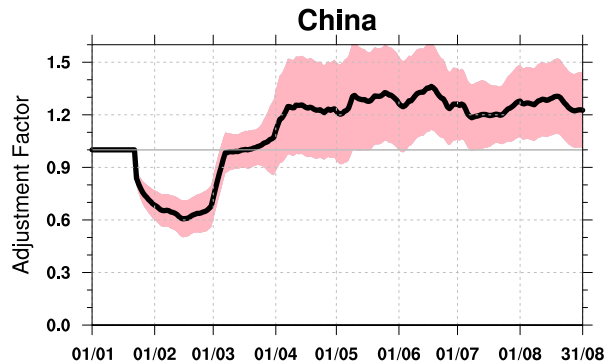
18. Line 406: Should be Figure 6 for power and Figure 4 for Industry?

Yes, Figure 4 is for the industry sector and Figure 6 for the power as indicated in the legend of the figures. The correct number has been included in the text.

19. Lines 411-412: Power AFs for China is not consistent with (Liu et al., 2020) and (Han et al., 2021), I provided the daily coal consumption data for six major power generation groups at the end of minor comments for your reference.

As already mentioned in our response to comment 14, the AFs for the power sector in China were estimated on the basis on emission data published by Forster et al., 2020. At the time we were writing the paper, this was the only data we had access to. However, the comparison between the Forster et al., 2020 and Han et al., 2021 data shows rather similar AF trends as indicated in the figure below.
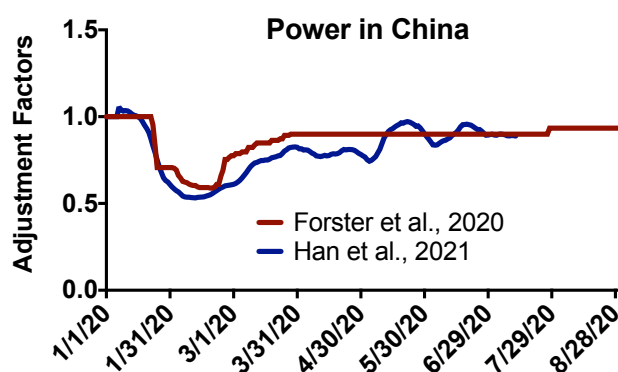
20. Line 426: change the red color "is" to black;

We have changed the text accordingly.

21. Lines 449-450: NMVOCs are mainly from solvents and industrial processes (Lines 464-465), and not homogeneous with SO2? Here "rather similar" seems to show some relations?

22. Lines 478-480: Expand this short paragraph a bit;

23. Line 486: "largest" or "large"?

24. Line 513: "might" or "could" or "did"?

25. Draw vertical lines to show lockdown and unlock date information in time series figures for major countries or regions.

References added to the manuscript:
Han, P. F., Cai, Q. X., Oda, T., Zeng, N., Shan, Y. L., Lin, X. H., and Liu, D.: Assessing the recent impact of COVID-19 on carbon emissions from China using domestic economic data, Science of the Total Environment, 750, 2021.

He, Y., Pan, Y., Gu, M., Sun, Q., Zhang, Q., Zhang, R., and Wang, Y.: Changes of Ammonia Concentrations in Wintertime on the North China Plain from 2018 to 2020, Atmospheric Research, doi: https://doi.org/10.1016/j.atmosres.2021.105490, 2021. 105490, 2021.

Liu, Z., Ciais, P., Deng, Z., Lei, R., Davis, S. J., Feng, S., Zheng, B., Cui, D., Dou, X., Zhu, B., Guo, R., Ke, P., Sun, T., Lu, C., He, P., Wang, Y., Yue, X., Wang, Y., Lei, Y., Zhou, H., Cai, Z., Wu, Y., Guo, R., Han, T., Xue, J., Boucher, O., Boucher, E., Chevallier, F., Tanaka, K., Wei, Y., Zhong, H., Kang, C., Zhang, N., Chen, B., Xi, F., Liu, M., Bréon, F.-M., Lu, Y., Zhang, Q., Guan, D., Gong, P., Kammen, D. M., He, K., and Schellnhuber, H. J.: Near-real-time monitoring of global CO2 emissions reveals the effects of the COVID-19 pandemic, Nature Communications, 11, 5172, 2020.

Sun, Y., Lei, L., Zhou, W., Chen, C., He, Y., Sun, J., Li, Z., Xu, W., Wang, Q., Ji, D., Fu, P., Wang, Z., and Worsnop, R. D.: A chemical cocktail during the COVID-19 outbreak in Beijing, China: Insights from six-year aerosol particle composition measurements during the Chinese New Year holiday, ence of The Total Environment, 742, 2020.

Zhang, Q., Pan, Y., He, Y., Walters, W. W., Ni, Q., Liu, X., Xu, G., Shao, J., and Jiang, C.: Substantial nitrogen oxides emission reduction from China due to COVID-19 and its impact on surface ozone and aerosol pollution, Science of The Total Environment, 753, 142238, 2021.

Zheng, B., Geng, G. N., Ciais, P., Davis, S. J., Martin, R. V., Meng, J., Wu, N. N., Chevallier, F., Broquet, G.,
Boersma, F., van der Ronald, A., Lin, J. T., Guan, D. B., Lei, Y., He, K. B., and Zhang, Q.: Satellite-based estimates of decline and rebound in China's CO2 emissions during COVID-19 pandemic, Science Advances, 6, 2020.