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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Observed decreases in on-road CO_2 concentrations in Beijing during COVID-19" *by* Di Liu et al.

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Reply to reviewer's comments:

We appreciate the careful evaluation and many important comments from the reviewers. We made additional analyses and major revisions to the paper, including the following: 1) Uncertainty analysis for observation instruments and significance test 2) The impact of the biological (vegetation) sink. 3) We rewrote and reorganized the on-road CO2 and enhancement results and statement.

Below, we describe these changes in detail and address comments and suggestions point-by-point.

Please see the supplement to this comment for figure details and blue font response.

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Discussion paper

Reply to Reviewer 1:

The MS mainly deals with atmospheric CO2 concentrations measured during 6 on-road observation trips in Beijing, China using mobile platforms before (1 trip), during (3 trips) and after (2 trips) the local COVID-19 restrictions. The topic belongs to the scope of the ACP, it is timely and of research interest. The general levels of the evaluations and discussion, however, should be largely improved. Due to this severe contradiction, which is documented in the comments listed below as examples, the evaluation of the MS cannot be performed unambiguously. Major comments 1. To reduce the weather and background impacts on the atmospheric concentrations, the authors selected the days which were similar to each other as far as the local weather is concerned. They used reality photos collected from the IAP tower, PM2.5 mass concentrations and WS data for this purpose. Looking at the photos and PM2.5 data, it seems, however, that some days were rather different from the others. The PM2.5 mass concentrations, for instance, changed from 6 to 169 microg m-3. Do these conditions really represent similar weather? (Furthermore, can the latter case indeed be classified as “Light polluted day”?) In addition, one can only wonder why the authors did not use visibility data (possibly available from the AP tower as well) instead of photos, which are demonstrative character only. Thank you for your comments and suggestions. We may have misled you and the readers. We reorganized the Results section in the revised manuscript. We conducted six observation trips, one trip for before COVID-19 restrictions (BC), four trips for during COVID-19 restrictions (DC) and one trip for after COVID-19 restrictions (AC). We only used 2 DC trips (on 21st and 22nd February 2020) from 4 DC trips, which we ensured that the weather conditions were as similar as possible. Therefore, we compared the CO2 concentrations on the roads using these 4 trips (1 trip for BC, 2 trips for DC and 1 trip for AC) with similar weather conditions. The other two trips were also plotted and are shown in the Results section, but they were not used for comparison. Although these 4 trips (2 DC trips with the most similar weather conditions, 1 BC trip and 1 AC trip) were labelled as having the most similar weather conditions, their weather conditions were still different (from table 1, the PBLHs and wind speeds were

not exactly the same), and they were still impacted by background CO2 fluctuations. Therefore, to further reduce these impacts, we used the enhancement method. We found that this method works for both the 2 clear-day DC trips (labelled as having the most similar weather conditions) and the 2 polluted-day DC trips (on 13th and 20th February 2020). February 13th (PM2.5 equalled 169), was heavy pollution day. We have revised accordingly. Thanks! We did not find visibility data for the IAP tower.

2. More importantly, the planetary boundary layer height (PBLH) - which is an important property that can affect the actual concentration of pollutants emitted from surface sources - was not taken into consideration and discussed. The same arguments partially hold for precipitation (and for vegetation activity over the months). All these should be included and addressed in detail in the revised MS. Thank you for your suggestions. We added PBLH data from GFS in Table 1 and added a discussion in the "Methods and Data" and "Results" sections. To understand the CO2 variability impacted by natural sinks (especially for vegetation), we used the dynamic vegetation and terrestrial carbon cycle model VEGAS (Zeng et al., 2014) to simulate the terrestrial biosphere-atmosphere flux (Fta) in Beijing during 2000-2020 (SFigure 3). The model was run at a 2.5×2.5-degree resolution from 1901 to June 2020, forced by observed climate variables, including monthly precipitation and hourly temperature. Although precipitation and temperature in 2020 were higher than the climatology (average of last 20 years), the difference between the Fta in 2020 and the average was within one standard deviation. We also analysed the CO2 concentration at the Shangdianzi station in the Beijing rural region, which is one of the three WMO/GAW regional stations in China, to determine the CO2 background variation (Fang et al., 2016). The results (SFigure4) showed that the background CO2 concentration variation mainly induced by natural factors from February to May was only approximately 5 ppm.

However, these two factors (vegetation flux and natural changes) both indicate areas far larger than Beijing urban areas. Because the location of the IAP tower and the tracks of the on-road observations are both in urban and we used enhancement method,

these factors were reduced.

3. The number of trips (1/3/2) was rather limited. The authors should discuss the representativity of their results and conclusions. Of the 6 trips, there were 5 trips performed on weekdays and 1 trip on weekend. The authors should clarify their statement that "During COVID-19, there was no significant difference between weekdays and weekends." Could this sentence be made more specific or is the number of trips sufficient for the conclusion. Thank you for your suggestions. We agreed with your suggestion, and we revised the statement as "during COVID-19 restrictions, there was no difference between weekdays and weekends during working hours (9:00-17:00 local standard time, LST)." We also added a traffic flow map for the 4 DC trips (SFigure 2) during working hours to validate our statement. The map shows that during the working hours of the 4 DC trips, the traffic conditions in Beijing were all smooth. As representatives of the results and conclusions, we conducted six trips in this study, which covered both weekdays and weekends, both clear days and polluted days and both rush hours and working hours. We obtained robust signals when we used the enhancement method. When we analysed the results, we categorized the results according to weekdays/weekends, working/rush hours and ring roads/other roads to ensure that the results were comparable. 4. L78-80: The authors state ". . . the enhancement, which calculates the difference in the CO2 concentration between urban and rural background observations, could effectively reduce the influence of background CO2 concentration fluctuations to analyze CO2 concentration characteristics in urban areas. . .". The IAP tower is, however, located in the city, and there are no arguments why it should be considered as the background environment. The authors refer to its values only as baseline concentrations, which were obtained at the lower or surface levels. One can wonder if the area of the trips and the site of the tower (in particular at lower levels) are influenced by the same environmental conditions. In addition, what is the prevailing wind direction in the area? Thank you for your suggestions. First, the 280-metre level data from the IAP tower have good representativity because they have an average fetch of approximately 17 km, which covers a major part of Beijing's urban areas. Unfortunately, 280-metre

level data were missed due to the instrument (sampling pump) malfunctions, and we obtained only surface and lower-level data. Second, the monthly averaged CO2 from different levels according to Cheng et al. (2018) showed a relatively stable difference among different heights (shown below). The results showed that the 8-metre level was approximately 40 ppm higher than 280 metres level in February and approximately 30 ppm higher in May. Therefore, the AC enhancement should increase by 10 ppm additionally. And this result supports with our hypothesis.

Third, there are no large emissions sources near the IAP tower. The prevailing wind direction during these trips was northwest.

5. The MS is extremely difficult to read which detracts from its values. It should be better organized, some strange citation practice (e.g. L58: . . . from Le Quere et al.(Le Quere et al., 2020)), the rounding off strategy (e.g. L51: . . . emissions dropped abruptly by 53.4%), oversophisticated formulations or non-consistent presentations (e.g. Fig. 1, panels C and D: color coding/line representation reversed, it contains dashed and not dotted lines as specified), spelling mistakes (L61: . . . difficult to detect a decrease in the urban CO2 concentration decrease directly) and frequent redundant repetitions should be carefully revisited and corrected. This all implies that the authors should have paid more attention to finalizing their MS. Thank you! We have carefully edited the manuscript and corrected all the instances you pointed out and several other places. We also reorganized and rewrote the Results section. Regarding the strange citation practice, a technical error occurred when we used Endnote software to automatically generate citations in MS Word document, we have carefully checked and revised the manuscript.âĂČ References: Cheng, X. L., Liu, X. M., Liu, Y. J., and Hu, F.: Characteristics of CO2 Concentration and Flux in the Beijing Urban Area, Journal of Geophysical Research-Atmospheres, 123, 1785-1801, 10.1002/2017jd027409, 2018. Fang, S. X., Tans, P. P., Dong, F., Zhou, H., and Luan, T.: Characteristics of atmospheric CO2 and CH4 at the Shangdianzi regional background station in China. Atmospheric Environment, 131, 1-8, 2016. Kutsch, W.,

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Please also note the supplement to this comment:
https://acp.copernicus.org/preprints/acp-2020-966/acp-2020-966-AC1-supplement.pdf

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