Response to the Referee #3

We thank the reviewer for his/her interesting comments. The answers to the reviewer's questions are highlighted in red below.

This study provides spatially resolved sectorial adjustment factors (AFs) of emissions during the COVID lockdown. As pointing out by the authors, this database is expected to be directly applied in emission changes which can be further used in global or regional inventories in air quality modelling.
While this database is useful and desires for a publication in ESSD, I think it is necessary and helpful to clarify:

1) For road transport, while the information from Google or Baidu maps provides generally the transport intensities on road, emissions from different vehicle types and gasoline/diesel are different. Were this considered in the emission AFs ?

As a general comment, the CONFORM dataset was designed to be directly applicable to existing global and regional inventories (those used by chemical transport models) that use relatively similar sectors (EDGAR, ECLIPSE, CAMS, MEIC, REAS, etc.). These inventories include emissions from the following six major sectors: industrial processes, road transportation, power generation, residential, aviation and shipping. As stated in the paper, we developed adjustment factors for the sectors used in these or similar inventories; however, these inventories do not provide information on emissions by vehicle or fuel type. It is worth noting that our approach is similar to that used for greenhouse gases (e.g. Le Quéré et al., 2020).

To clarify this point raised by the reviewer in the manuscript, we have added the following text to the introduction section: " The inventories commonly used in these models (EDGAR (Crippa et al., 2018), ECLIPSE (Klimont et al., 2017), CAMS (Granier et al., 2019), MEIC (Li et al., 2017), etc.) include the sectors already mentioned (industrial processes, road transportation, power generation, residential, aviation and shipping). The emissions of these sectors are developed on the basis of a combination of several sub-sectors that are not provided separately in the emission inventories." (Lines 84-89).

2) Industrial sector- workplace change might be an indicator, as it is hard to get accurate and reliable data on this. But this estimation is expected to have much higher uncertainties, and the steel production activities are rather different from many others, for example, petroleum industry facilities most of which are not shut down during the COVID.

We highlighted the uncertainty in the estimation of AFs for industrial sector using Google's workplace category in lines 242-245 such as "… there are large differences in some countries between these data. For example, in Europe the greatest change in crude steel production is 24 % in comparison to 59 % estimated using Google's workplace category, indicating a high level of uncertainty in the AFs for the industry sector". The difference between the maximum AF estimated from steel production and Google's workplace is 35 %, which is within an order of magnitude of the maximum uncertainty estimated by Liu at al. (2020) for this sector of 36 %.
Furthermore, we mentioned in lines 398-399 of the manuscript that the AFs for the industrial processes sector are subject to average uncertainties ranging from ±20 to ±30 % depending on the regions.

3) For power plants, were data for electricity plants using different fuels- coal-fired, nuclear power, hydroelectric power etc.,

For the estimation of emission AFs in the power sector, we use total electricity load activity data from various fuels such as coal, gas, nuclear and hydroelectric power. However, as previously stated, the majority of current emission inventories commonly used for atmospheric modeling do not include emissions for these specific sub-sectors (coal, gas, nuclear power, hydroelectric power, etc.). As a result, the reviewer's requested level of detail is unavailable and cannot be applied to the inventories targeted by the CONFORM dataset.

4) Residential sector-I agreed with the authors that there was an increase in residential emissions, which could be also found in some recent studies finding high indoor air pollution (also leading to higher overall exposure) during the COVID in rural area. But in urban homes, the increased electricity contributed small to the increase of emissions (in fact in most emission inventories, residential electricity associated emissions are not counted in the residential sector), and gas burning for cooking increased very small. People had three meals per day, no matter it is during the COVID or not. However, the AFs based on the increased electricity data for London are not representative for other countries using solid fuels. Why not referring to information from other developing countries, especially those using solid fuels in rural area ?

Changes in emissions from the residential sector are difficult to assess across the different regions of the globe due to differences in the exact definition of the sector from one inventory to the next. For example, in Le Quéré et al. (2020), CO_2 emissions from the residential sector were estimated using a combination of confinement indexes and electricity consumption of the city of London, which was then extrapolated to the other countries. Liu et al. (2020) used fuel consumption data from 2019 that was scaled to 2020 based on the population-weighted heating degree days variation between these two years. Although a more detailed study based on national economic activity data that are not yet available in many countries could be conducted in the future. In this study, we used Google mobility reports (https://www.google.com/covid19/mobility/) and assumed that emission adjustment factors using Google's residential category are representative of the majority of domestic combustion activities (cooking, residential heating, heating water and other combustion activities) in many countries. We only used residential emissions from Le Quéré et al. (2020) to derive adjustment factors for China, as stated in lines 318-319 of the revised manuscript.

5) Besides changes in individual residential homes, there are significant changes in commercial emissions for example restaurants and the mall. Was this considered and available from some data ?

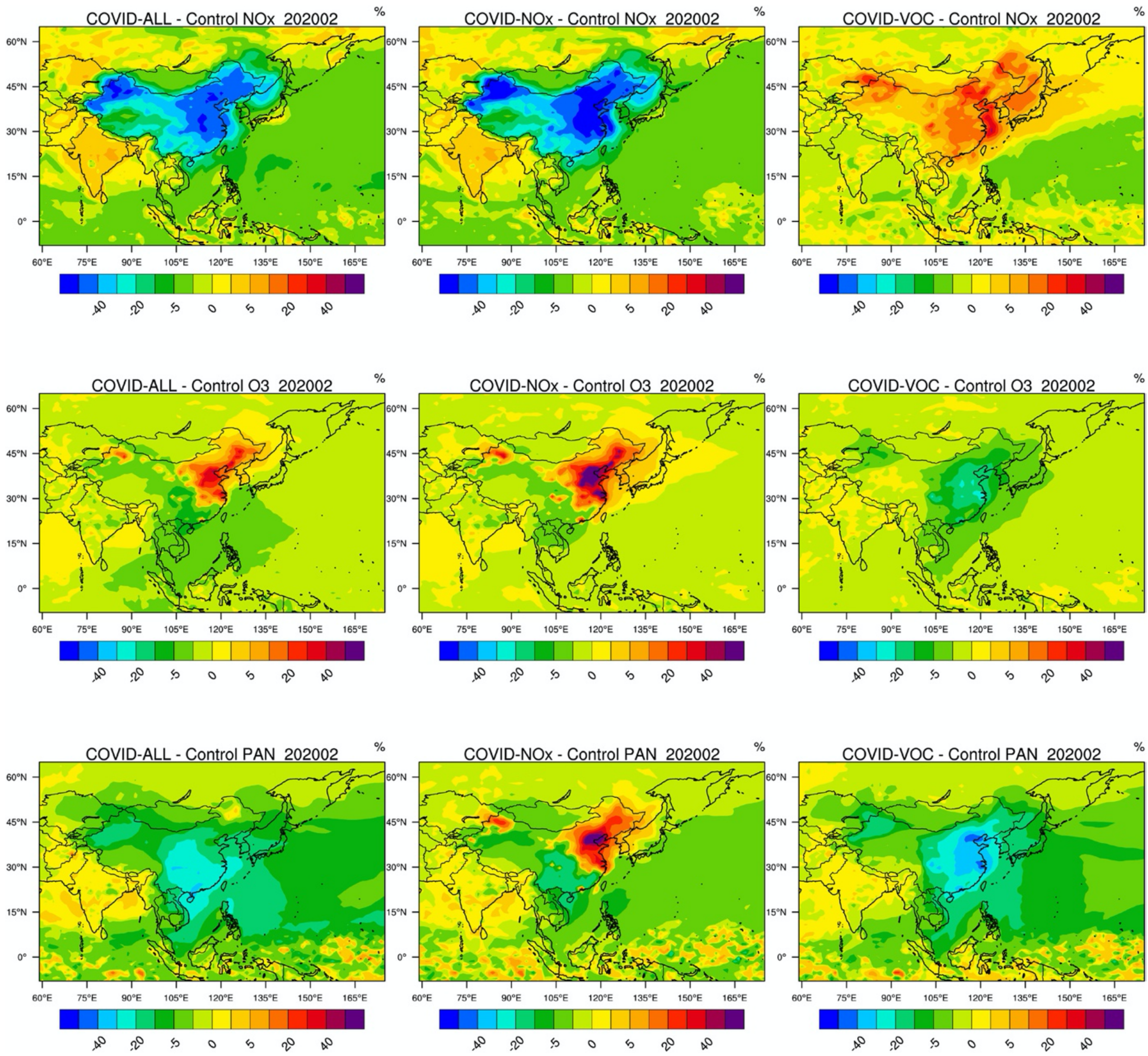
The residential sector is defined in the CONFORM dataset in the same way that it is defined in the EDGAR emission dataset (Crippa et al., 2018), namely as a sector that includes both residential and commercial activities. Almost all inventories lack precise information about the residential sector, and estimates of the residential and commercial sectors' contributions to emissions are currently unavailable. As stated in the previous answer, the lack of detailed information for estimating adjustment factors for the residential sector results in a high level of uncertainty for this sector, which is approximately 20 % in our study and approximately 40 % in the study of Liu et al., 2020, as indicated in the manuscript (Lines 416-419).

6) Emissions are different from different fuels- fossil and biomass ones. This is more obvious in residential sector, where multiple different fuels are used. Residential coal and biomass use contribute largely to the primary emissions of PM2.5, BC and OC. Were different AFs for different fuels types, and differences in pollutant species, considered in the development of database ?

As previously stated, the AFs are provided for a number of sectors that are commonly used in current emission inventories, such as energy, industry, residential, road transportation, aviation and shipping. Almost all of the inventories listed here and generally used in atmospheric models lack information on emissions by fuel type. AFs are calculated in our study on a sector, geographic, and temporal basis rather than by pollutant species.

7) Validation of results is always an important concern. It is accepted that global or regional emission inventory itself is difficult to be validated unless in couple with the air transport chemical models and validated in comparison to the monitoring data. This should be discussed in the manuscript, if it is presently not in the study scope.

The J. of Geophys. Res. has published an evaluation of our dataset (Gaubert et al., 2021). Both our current ESSD paper and the J. Geophys. Res. study were submitted in November 2020. Gaubert et al. (2021) performed simulations with the global Community Atmosphere Model (CAM-Chem), after applying the CONFORM dataset to the CAMS-GLOB-ANT_v4.2-R1.1 anthropogenic emissions. The figure below depicts the percentage change in the concentrations of many chemical compounds in China as a result of reduced primary pollutant emissions in February 2020 during the COVID-19 pandemic (Figure 6 in the J. Geophys. Res. publication). The figure shows that during the strict lockdown, the surface concentration of NOx was significantly reduced (40–50%) in most areas of eastern China and the country's northwest. At the same time, as evidenced by surface observations, ozone concentrations increased throughout the northeastern part of China and locally in a number of significant urban areas in other regions (e.g., Huang et al., 2020; Shi & Brasseur, 2020). In addition, there was a decrease in ozone in the southern part of the country. This finding is consistent with Liu and Wang's (2020) regional model analysis and surface observations (e.g., Fu, Wang, et al., 2020; Lian et al., 2020).



Another assessment of our dataset in China was published in the journal Science of the Total Environment (Liu et al., 2021). Using observed and predicted data, Liu et al. (2021) investigate the surface ozone before and during the lockdown. The CONFORM dataset was used in the CMAQ (Community Multiscale Air Quality model, v5.2.1) model (US EPA, 2018) after being applied to the MEIC (Multi-resolution Emission Inventory for China) regional emission inventory (Li et al., 2017). The findings show that reductions in anthropogenic emissions of ozone precursors (NOx and VOCs) contributed to changes in surface ozone that are consistent with observations. This newly published study has been cited in the revised manuscript (Lines: 450:454).

Bouarar et al. (2021), a paper submitted to Geophysical Research Letters, use the CAM-Chem model to evaluate the performance of CONFORM dataset by simulating the response of chemical species in the free troposphere. Another paper, based on TROPOMI and IASI satellite measurements and model simulations, was also recently submitted to GRL, and it investigated the impact of COVID-19 on NOx and VOCs chemical compounds over China. According to both studies, model simulations using anthropogenic emissions and the CONFORM dataset capture the observed variations in ozone concentrations in the free troposphere during the Northern Hemisphere spring/summer, as well as in spaceborne observations of NO_2 and VOCs in China.

References:

Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Dentener, F., van Aardenne, J. A., Monni, S., Doering, U., Olivier, J. G. J., Pagliari, V., and Janssens-Maenhout, G.: Gridded emissions of air pollutants for the period 1970–2012 within EDGAR v4.3.2, Earth Syst. Sci. Data, 10, 1987–2013, https://doi.org/10.5194/essd-10-1987-2018, 2018.

Forster, P. M., H. I. Forster, M. J. Evans, M. J. Gidden, C. D. Jones, C. A. Keller, R. D. Lamboll, C. Le Quéré, J. Rogelj, D. Rosen, C.-F. Schleussner, T. B. Richardson, C. J. Smith and S. T. Turnock: Current and future global climate impacts resulting from COVID-19, *Nat. Clim. Chan.*, 10, 913-919, doi:10.1038/s41558-020-0883-0, 2020.

Gaubert, B., Bouarar, I., Doumbia, T., Liu, Y., Stavrakou, T., Deroubaix, A., et al. (2021). Global changes in secondary atmospheric pollutants during the 2020 COVID-19 pandemic. Journal of Geophysical Research: Atmospheres, 126, e2020JD034213. https://doi.org/10.1029/2020JD034213.

Bouarar, I., B. Gaubert, G. P. Brasseur, W. Steinbrecht, T. Doumbia, S. Tilmes, Y. Liu, T. Stavrakou, A. M. Deroubaix, S. Darras, C. Granier, F. G. Lacey, J-F. Müller, X. Shi, N. Elguindi and T. Wang : Ozone Anomalies in the Free Troposphere during the COVID-19 Pandemic, 10.1002/essoar.10506600.1, 2021.

Fu, X., Wang, T., Gao, J., Wang, P., Liu, Y., Wang, S., et al. (2020). Persistent heavy winter nitrate pollution driven by increased photochemical oxidants in northern China. Environmental Science & Technology, 54(7), 3881– 3889. https://doi.org/10.1021/acs.est.9b07248.

Huang, X., Ding, A., Gao, J., Zheng, B., Zhou, D., Qi, X., & He, K. (2020). Enhanced secondary pollution offset reduction of primary emissions during COVID-19 lockdown in China. National Science Review, 8, nwaa137. https://doi.org/10.1093/nsr/nwaa137.

Le Quéré, C., R. B. Jackson, M. W. Jones, A. J. P. Smith, S. Abernethy, R. M. Andrew, A. J. De-Gol, D. R. Willis, Y. Shan, J. G. Canadell, P. Friedlingstein, F. Creutzig and G. P. Peters: Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement, Nat. Clim. Chang. 10, 647–665, doi:10.1038/s41558-020-0797-x, 2020.

Li, M., Liu, H., Geng, G., Hong, C., Liu, F., Song, Y., Tong, D., Zheng, B., Cui, H., Man, H., Zhang, Q., and He, K.: Anthropogenic emission inventories in China: a review, Natl. Sci. Rev., 4, 834-866, doi: 10.1093/nsr/nwx150, 2017.

Lian, X., Huang, J., Huang, R., Liu, C., Wang, L., & Zhang, T. (2020). Impact of city lockdown on the air quality of COVID-19-hit of Wuhan city. Science of the Total Environment, 742, 140556. https://doi.org/10.1016/j.scitotenv.2020.140556.

Liu, Y.M., Wang, T., Stavrakou, T., Elguindi, N., Doumbia, T., Granier, C., Bouarar, I., Gaubert, B., Brasseur, G.P. Diverse response of surface ozone to COVID-19 lockdown in China. Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2021.147739 (In Press).

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., Schellnhuber, H. J.: Near-real-time monitoring of global

CO_2 emissions reveals the effects of the COVID-19 pandemic, Nat. Commun. 11, 5172, https://doi.org/10.1038/s41467-020-18922-7, 2020.

Shi, X., & Brasseur, G. P. (2020). The response in air quality to the reduction of Chinese economic activities during the COVID-19 outbreak. Geophysical Research Letters, 47, e2020GL088070. https://doi.org/10.1029/2020gl088070.

Stavrakou, T., J.-F. Müller, M. Bauwens, T. Doumbia, N. Elguindi, S. Darras, C. Granier, I. De Smedt, C. Lerot, M. Van Roozendael, B. Franco, L. Clarisse, C. Clerbaux, P.-F. Coheur, Y. Liu, T. Wang, I. Bouarar, X. Shi, B. Gaubert, S. Tilmes, G. Brasseur: Impact of COVID-19 on NOx and VOC compounds over China based on TROPOMI and IASI satellite observations and model simulations. Submitted to Geophysical Research Letters, 2021.

United States Environmental Protection Agency. (2018). CMAQ (Version 5.2.1) [Software]. Available from https:// doi:10.5281/zenodo.1212601.