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Reply on RC1

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Author comment on "Diagnosing ozone–NO_x–VOC sensitivity and revealing causes of ozone increases in China based on 2013–2021 satellite retrievals" by Jie Ren et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-347-AC1, 2022

We are grateful to the reviewer for the thoughtful and constructive comments, which are helpful for significantly improving the manuscript. We will respond to each comment in detail in the revised manuscript. The short responses are provided here first.

1. Novelty. Firstly, higher resolution TROPOMI data is used to improve the accuracy of estimating the HCHO/NO_2 thresholds in different regions of China. Secondly, some methodology details for establishing the relationship between O_3 and HCHO/NO_2 are different from those mentioned by the reviewer. Thirdly, O_3 sensitivity distributions in China are updated to 2021 using these thresholds and the reasons why ozone concentrations increased in recent years combined with long-term variation trends of ozone precursors and short-term change cases are explored. Furthermore, optimal VOC/NOx reduction ratios for three typical cities are provided. We will emphasize uniqueness and novelty in the revised manuscript.

2. Significance of TROPOMI data.The higher resolution of TROPOMI satellite data enables a more accurate match between the location of ground-based O3 monitoring stations and the grid of satellite data, thus allowing a more accurate derivation of HCHO/NO2 thresholds and a more accurate reflection of the spatial distribution of ozone sensitivity. In addition, OMI data at some times are missing in the products from QA4ECV. Therefore, we adjusted the OMI data before 2018 to combine it with the TROPOMI satellite data. The relevant explanation will be added in the revised manuscript.

3. Cases during COVID-19. This section is to verify the O_3 sensitivity in cities in typical cases with the particular changes in emission and ozone concentration in the short term.

This study focuses on the O_3 sensitivity from April to September, the period when ozone exceedances are most likely to occur. In April 2020, Beijing is still under strict restrictions because of the epidemic control. Therefore, NO_2 concentration is significantly lower than those in 2019 and 2021, which is caused by the still restricted anthropogenic activities rather than by the air pollution control actions. Le et al. also reported a similar conclusion that NO_2 decreased and O_3 increased during the COVID-19 outbreak. The significant increase in HCHO concentrations in Chengdu in May 2020 implies an increase in VOC emissions. Song et al., 2021 also reported an increase in VOC concentrations. It could be explained by the vigorous development of stall business in Chengdu at that time in order to resumption of work and production. In both cases, the decrease in NOx and the increase in VOC, as well as unfavorable meteorological conditions, contributed to the ozone pollution events.

4. PM effects. Some studies suggested that concurrent decreases in the $PM_{2.5}$ level may be a potential driver of ozone increases in China, which may increase solar radiation and weaken the aerosol sink of HO_2 radicals and thus stimulate ozone production. However, the summertime MDA8 O_3 enhancement due to changes in emissions and $PM_{2.5}$ levels in NCP during 2013-2017 estimated by Li et al. (1 ppb $year^{-1}$) is insufficient to explain the observed trend (3.3 ppb $year^{-1}$) (Lu et al.), which indicates that the effect of $PM_{2.5}$ is not the essential cause of the deterioration of ozone pollution.

The results in this study show that it is the variation of the ozone precursors VOC and NOx that is responsible for the ozone concentrations. Our previous study also shows that O_3 concentrations in Beijing have declined in recent years in parallel with the significant decline in $PM_{2.5}$ concentrations, suggesting that the appropriate emission reduction ratio of VOC to NOx can control both $PM_{2.5}$ and O_3 pollution. A simple emphasis on "decreasing $PM_{2.5}$ leads to increasing ozone concentrations" could mislead the government to make the wrong policy decisions. More discussions will be supplied in the revised manuscript.

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