Reviewer #2

General Comments

The Covid-19 lockdown provides a unique opportunity for assessing the effects of substantial emission reductions on atmospheric chemistry. This paper used ambient measurements from a tower situated in the Pearl River Delta of China to explore the response of air pollutants to the lockdown. While this paper is within the scope of ACP, the present paper is limited to a cursory data analysis, without significant contribution to our existing knowledge. The absence of sound analysis accompanied by a lack of in-depth discussion of the observed phenomenon make this paper unpublishable in the present form. Besides the lack of novel insights, I found the manuscript overall hard to follow due to lots of typos throughout the manuscript. While addressing the specific comments below may improve the paper, I don't think these improvements could justify publication in ACP. Therefore, I would recommend this paper to be rejected.

Thanks for your comments. We have increased the depth of analysis, and collect and cite as many studies on atmospheric environment in PRD area as possible to support our conclusions in the revised manuscript. We hope that these efforts will make the manuscript more publishable.

Major comments:

1) Line 33-34: Why photochemical reactions are not considered as a significant ozone source? While anthropogenic emissions are low during the lockdown period, the oxidation of biogenic VOC still contributes to the ozone formation given the elevated BVOC emissions over the PRD.

The fact supporting that photochemical reactions are not the main source of ozone is that the diurnal curve is much flatter during the lockdown period than during the pre-lockdown period, and the MDA8O_3 values during the lockdown period is much lower than that of the pre-lockdown period, which means the chemical reactions generating and consuming O_3 are much more inactive during the lockdown period. Furthermore, in winter, the BVOC emission from plant is much weaker than in summer. However, we will revise the statement of Line 33-34 and will emphasize possible effect of BVOC on generating O_3, especially on generating the weak peak of O_3 diurnal curve at noon.

2) Line 150-158: Please consider simplifying these statements since they are not key contents regarding scientific publication.

The reason why the whole process of lockdown measures is introduced in detail is to help understand the reasons leading to the variation of pollutant curves in Figure 2. We have simplified it as follow.

"The first case of COVID-19 in Shenzhen was reported by local news outlets on 15 January 2020, which is the starting date for the reduction of citizens' outdoor activities. On 23 January, the Guangdong province, where Shenzhen is located, activated its top-level emergency response on this day, and all residents in Shenzhen were instructed not to leave their homes unless necessary."

3) Line 196: The authors mention that "observed at different heights". Does the data presented in Figure 1(a)-(c) represent the average value of vertical observations? Please clarify.

Yes, the pollutant concentration curves in Figure 2 are the average values for the whole vertical layer of observation. We have clarified it in the revised manuscript.

4) Line 205-209: I suggest removing these contents since the MDA8 ozone is a well-known indicator that is used to infer the magnitude of ozone pollution.

In order to maintain the integrity of the paper, we intend to retain the explanation of $MDA8O_3$, while we have simplified it as follow.

"$MDA8O_3$ is defined as the maximum 8-h moving average ozone concentration in a natural day, which is generally used to assess the severity of O_3 pollution."

5) Line 210: Please clarify the potential reasons for this phenomenon. Possibly attributed to less titration effects of NO because primary NO_x emission substantially decreased.

Yes, we agree with the comment. The higher average O_3 during the lockdown period might be attributed to the low NO at night, therefore, although the daytime average O_3 during the lockdown is much lower than that during the pre-lockdown, the daily average during lockdown is higher than that during the pre-lockdown. In the revised manuscript we emphasized the titration effects of NO_x as follow.

"The ratios were generally greater than 1.0 in night, which clearly demonstrated less effective NO_x titration at night which leads to relatively higher ozone concentrations at night compared to pre-lockdown period."

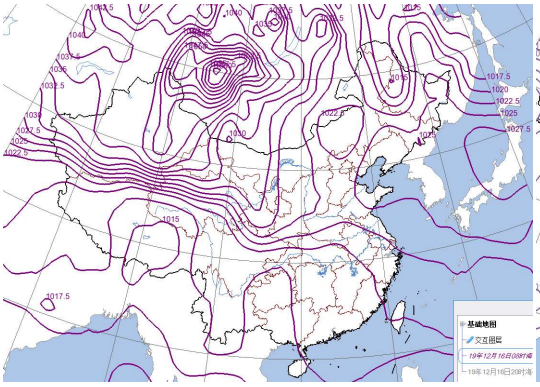
6) Line 216-219: Please clarify the reason for the comparison of air pollutants and meteorological parameters between 2017 and 2020. Does the meteorological condition quite similar? Otherwise, it is not comparable.

The large scale circulations in the two periods were quite similar and the dominant wind direction were same, while the ground observed meteorological parameters were somehow different for stronger cold fronts in December 2017. The reason why the data in 2017 is included in the current study is that data in 2017 would provide more information on the long-term changes in pollutant concentration, emissions and climate.

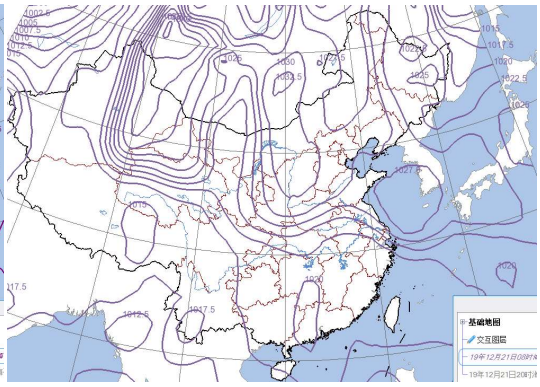
7) Line 257-259: While the observations from the tower depict insignificant variations in meteorological parameters, the mesoscale process and large-scale synoptic pattern could still alter the air pollutants levels. I don't think the evidence is sufficient to make the conclusion.

Actually, in light of the classic theory on atmospheric diffusion, most of the influences of mesoscale or large-scale synoptic pattern on the pollutant concentrations are realized by the meteorological elements within boundary layer, such as wind speed, wind direction, relative humidity and temperature stratification, which determine the diffusion and transportation capability of the atmosphere (Pasquil, 1961; Pasquil, 1978; Gifford, 1961). Thus the comparison of the observed meteorological elements at the tower base during different period can used to determine whether the diffusion condition is similar or not. In response to your comments, we have added some information on the synoptic pattern analysis during the two periods, to further support our conclusion. We put the surface weather maps (1 map every 5 days) used to analyze the synoptic pattern below, from which it can be found that during the period of study, Shenzhen was primarily controlled by uniform pressure or weak high pressure ridge with sparse ground isobaric lines for most of the study period, which were quite typical circulation pattern in this area in winter. At the same time, We have weakened the tone on judging whether the weather is the major reason leading to the sudden change of the pollutant concentrations and have changed the word "impossible" into "unlikely".

2019-12-16



2019-12-21



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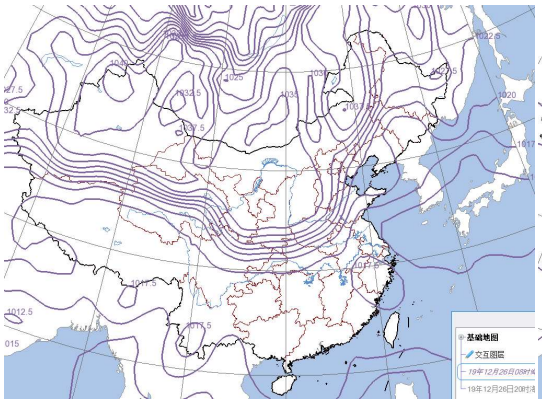

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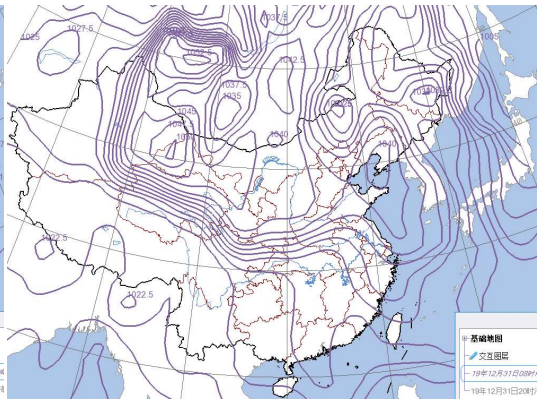
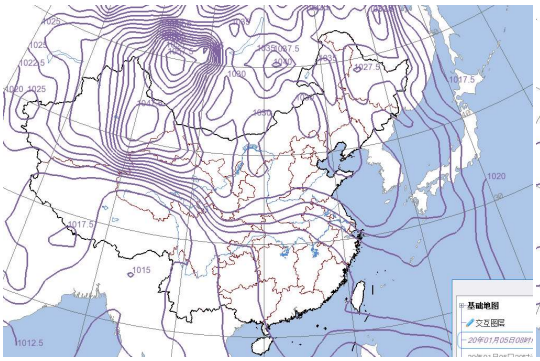


2020-01-05



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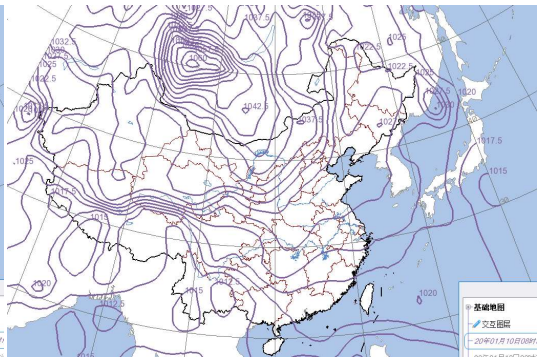

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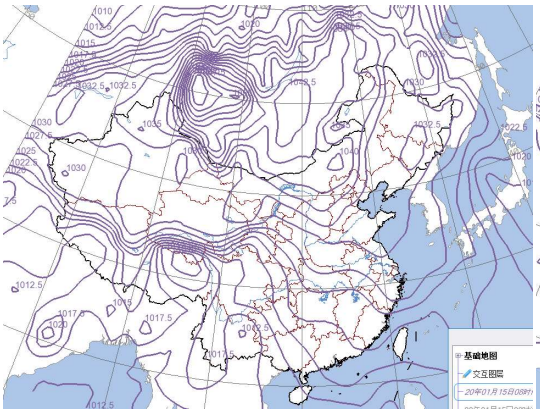

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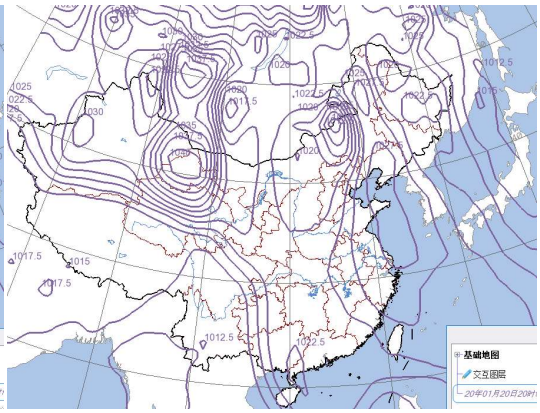

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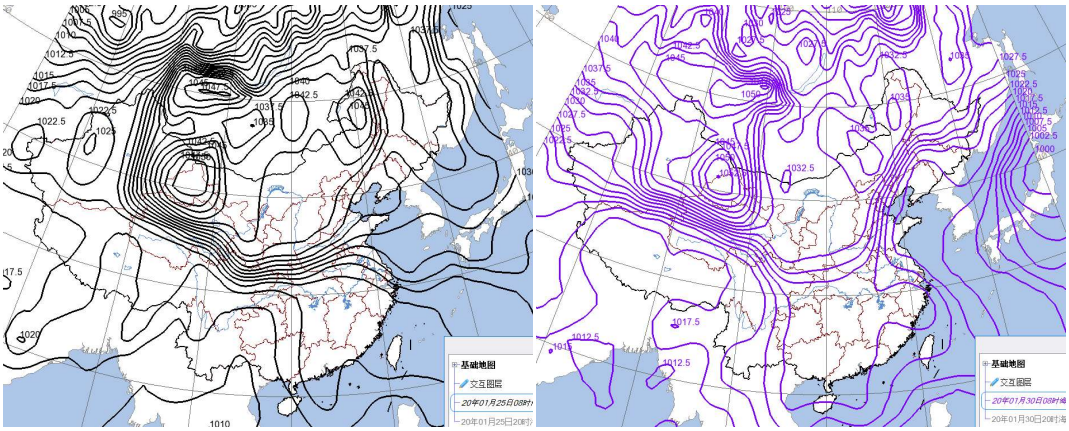

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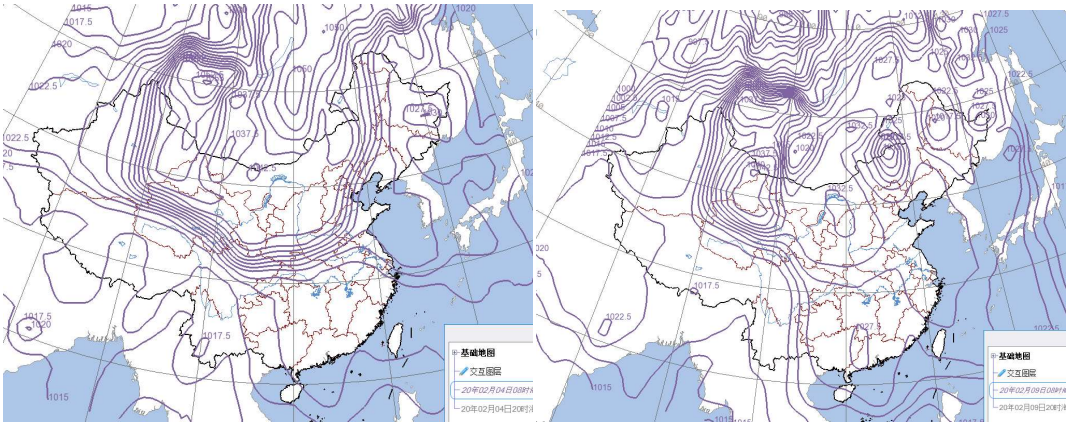

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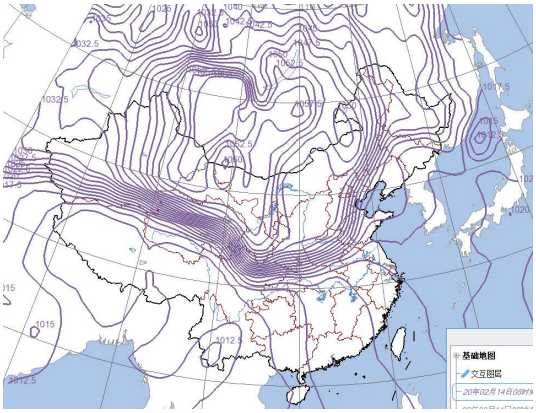

Figure R1 The surface weather maps during the period of study, the time of the map isin the lower right corner

References:

Pasquil F., The estimation of the dispersion of windborne material. Meteorol. Mag., 90: 33-49, 1961.

Pasquil F., Atmospheric dispersion parameters in plume modeling. US EPA, 1-58, 1978.

Gifford F. A., Use of routine meteorological observations for estimating atmospheric dispersion. Nuclear

Safety, 2(4): 47-51, 1961.

8) Line 270-272: The authors indicate that nearby forests constrain the dispersion of PM while this explanation appears contradictory to the phenomenon that PM levels at 110-120m are higher than ground-level. The authors should comment on this interesting behavior.

Because it is located in a water source protection area and surrounded by a litchi forest, there is no direct pollution source within 100m around Shiyan base. The pollutants affecting the base come from the surrounding high ways, airports and urban built-up areas. The litchi forest surrounding SZMGT is about 10m high, which can prevent the pollutants transported from the outside of the forest from reaching the measurement site on the ground, while cannot prevent them from reaching the measurementat the height of 110-120 m.

9) Line 331-332: actually, ozone levels did not increase at night (as seen in Figure 5). The elevated ratio clearly demonstrates less effective NO_x titration at night which leads to relatively higher ozone concentrations at night compared to pre-covid.

We agree that less effective NO_x titration at night which leads to relatively higher ozone concentrations at night during the lockdown period and have addedsome discussion in the revised manuscript as follows:

"The ratios were generally greater than 1.0 in night, which clearly demonstrated less effective NO_x titration at night which leads to relatively higher ozone concentrations at night compared to pre-lockdown period. While the ratios were less than 1.0 in daytime, which showed that during lockdown, the concentration of O_3 decreased in daytime."

10) Line 383: The PRD is well-known for the substantial biogenic VOCs emitted from vegetation and it is highly possible that the enhanced HCHO column depicted by TROPOMI is attributed to the oxidation of biogenic hydrocarbons. I suggest the authors discuss the type of trees nearby the tower (possibly broadleaf trees that have strong BVOC emission potential).

Yes, we agree that the PRD region is a place with intensive BVOC emission and the enhancement of HCHO during the lockdown maybe produced by BVOC oxidation. According to the cited reference (Liu et al., 2021) in Line 383, the enhancement of HCHO is insignificant with 1.4%, if the anthropogenic emission of HCHO during COVID-19 decreased, the secondary formation should be enhanced to compensate the anthropogenic decrease. A recent study (Wu et al., 2020) showed the Leaf area index in PRD in autumn and winter is relatively large in China, and the winter BVOC mainly emitted by needleaf trees in PRD region. Nevertheless, the winter emission of BVOC is still not comparable with that in summer time. We believe that this oxidation of BVOC in winter is very increasing issue and more studies can be conducted in future with observation dataset. The above information has been added in the revised manuscript..

References:

Wu, K, Yang, X Y, Chen, D, Gu, S, Lu, Y Q, Jiang, Q, Wang, K, Ou, Y H, Qian, Y, Shao, P, Lu, S H.. Estimation of biogenic VOC emissions and their corresponding impact on ozone and secondary organic aerosol formation in China. Atmospheric Research 231. 2020

Liu, S., Liu, C., Hu, Q., Su, W., Yang, X., Lin, J., Zhang, C., Xing, C., Ji, X., Tan, W., Liu, H., Gao, M.. Distinct regimes of O3 response to COVID-19 lockdown in China. Atmosphere. 12,184. 2021

11) Line 413: I am confused by the statement that PM and ozone don't have related source. As widely acknowledged in-field measurements and laboratory work, both NO_x and VOCs from anthropogenic and biogenic are important precursors for secondary pollutants (PM, ozone).

We confirm that the statement is not suitable. During the lockdown period, a stronger Pearson correlation coefficient indicate that a possibility that the formation of one or several PM compounds (such as SOA and nitrate) is largely linear correlated withO_3, while a weak correlation between them during the pre-lockdown cannot conclude that the PM and ozone don't have related source due to the possible nonlinearity of difference PM compounds related to O_3. Here, we remove the statement.

Minor comments:

1) Please clarify the aim of this study in the last paragraph of the Introduction.

Thanks for the suggestion, we have added the aim of this study in the Introduction Section as follow.

"The purpose of this study is to analyze the change of vertical distribution of atmospheric pollutants induced by an extreme reduction of human activities, and to explore possible mechanisms causing the change, so as to provide scientific support for atmospheric environmental governance, especially the coordinated control of $PM_{2.5}$ and O_3 concentrations."

2) The grammar is in need of much attention. I suggest the authors carefully read through the manuscript and correct typos.

We will polish the language throughout the manuscript accordingly before a possible resubmission.

Technique typos:

Line 30: remove "dominant".

Line 81: scholars->studies

Line 92: air quality factors->air pollutants levels

Line 106: population->residents

Line 113: Do you mean "favorable to the accumulation and formation of air pollutants"?

Line 145: Elements->parameters

Line 155: her->the

Line 174: substantial ->significant

Line 301: prevention->mitigation

Line 319: furtherly->further

Line 435-437: remove "to be".

Line 480: curves->pattern

Corrected accordingly. Thanks.