#Reviewer 1

Chen et al. reported a comprehensive analysis of the abrupt increase of surface ozone observed in the North China Plain on the night of July 31 2021. The authors employed various datasets and tools in their analysis, including (1) the air pollutant observational data from the national monitoring stations, (2) high-frequency ground-based observational data during a campaign in this region, (3) vertical profile observation of ozone, (4) radiosonde meteorological data, (5) reanalysis data, (6) regional meteorological model, and (7) back-trajectory model. They found out that the sudden increase of surface ozone was not due to horizontal transport; instead, the dying typhoon and a local mesoscale convective system brought the high-ozone/low-CO air to the lower troposphere and even the ground surface. The authors did a commendable job by applying various tools to analyze a unique atmospheric phenomenon that has implications for air quality management. I support acceptance of the paper once the following concerns are addressed.

Thank you very much for your helpful suggestions which help us improve our manuscript substantially. We have modified our manuscript according to the comments.

General comment:

1. The authors emphasized that this paper is about the effect of a "dying" typhoon and "shallow" convection in the title, abstract, and many places in the main texts. While this is correct based on the authors' analysis, I wonder would it be better to generalize the mechanism? If I understand correctly, a typhoon (dying or not) likely causes stratospheric ozone that brings the stratospheric ozone to the upper and middle troposphere, and a follow-up mesoscale convective system (shallow or not) would then transport the high-ozone/low-CO air further down to the lower troposphere.

Several researchers have found that a large portion of stratospheric intrusions reach the top of planetary boundary layer (PBL), while only a few of them could penetrate into the ground surface (e.g., Ott et al., 2016; Trickl et al., 2020). This study addressed a coincidence of conditions for direct stratospheric intrusion to the surface including the large-scale typhoon and the meso-scale convective systems (MCSs). At first, the dying typhoon induced stratospheric intrusion into the middle-to-low troposphere, and then the MCSs facilitated the transport pathway of stratospheric ozone-rich air to contact the surface, and hence affected the surface air quality.

Ott, L. E., Duncan, B. N., Thompson, A. M., Diskin, G., Fasnacht, Z., Langford, A. O., Lin, M., Molod, A. M., Nielsen, J. E., Pusede, S. E., Wargan, K., Weinheimer, A. J., and Yoshida, Y.: Frequency and impact of summertime stratospheric intrusions over Maryland during DISCOVER-AQ (2011): New evidence from NASA's GEOS-5 simulations, J. Geophys. Res., 121, 3687–3706, https://doi.org/10.1002/2015JD024052, 2016.

Trickl, T., Vogelmann, H., Ries, L., and Sprenger, M.: Very high stratospheric influence observed in the free troposphere over the northern Alps - just a local phenomenon?, Atmos. Chem. Phys., 20, 243–266, https://doi.org/10.5194/acp-20-243-2020, 2020.

2. Meng et al. (2022) reported a very similar process (an anomaly in surface ozone due to the passing typhoon) in the same region (NCP). I am aware that the authors of the present work started their analysis before this recent paper (Meng et al., 2022) was published, but it would be beneficial to the readers if the authors could add some relevant discussions.

Thank you for your suggestion and the reference. We also agree that convective systems including typhoons can induce significant stratospheric intrusion and alter the meteorological conditions necessary for ozone production and accumulation. Case study and statistical analysis of typhoon's impacts on ozone variations would improve our understandings of the role of such synoptical convective systems played in ozone budget and air quality. The reference paper has been added in the manuscript.

3. The designs of the manuscript and figures require some improvements:

(1) Section 2.3, please add a figure (at least in the supplement) showing the domain setting of the WRF simulation. I would like to know whether the inner domain covers the region with strong vertical transport.

Thank you for your suggestion, the domain coverage used in the simulation is shown in Figure S1 in the supplementary file.

(2) In The paragraph starting at line 174, a table listing all WRF model parameterizations and setups will be very clear.

Thank you for pointing this out, the table of basic WRF settings is added in Table 1 (Section 2.3).

(3) Line 191, why not describe the setup of FLEXPART-WRF here? How many simulations? What is the location (lat, long, and altitude) of particle release? How many days for each simulation?

Thank you for pointing this out. The FLEXPART is driven by meteorology field from high-resolution WRF model output. The locations of backward trajectory simulations were set to Binzhou and Qingdao city between 1000-950 hPa at 04:00 LST on 1 August (Line 412-417). The time length of simulations was 28 hour.

(4) Line 194-197, these two sentences seem out of scope. Consider removing. I don't think it is necessary to mention the increase in ozone in the past decade in this region.

Thank you for your suggestion. We have removed these sentences.

(5) Line 208-210, this sentence is a bit odd too. Consider removing.

Thank you for your suggestion. We have removed this sentence.

(6) Figure 2, showing the "departure from the 10-day averaged ozone", is not a good choice to demonstrate the sudden increase of surface ozone. Instead, I believe Figure S2 (with the average diurnal pattern of ozone) is a much better option for showing the anomaly of surface ozone in this region. Similarly, I would recommend drawing a similar figure of CO to replace the original Figure 3.

Thank you. The variations of ozone concentrations are compared with their 10-day averaged value during which the NCP was influenced by Typhoon In-fa. It is rather clear to show the "weak" and "strong" phases of ozone variations as In-fa travelled through the NCP and emphasize the role of typhoon in influencing ozone concentrations.

(7) If possible, Figure 4 should also be replaced with one similar to the original Figure S2. In fact, in line 249, the authors stated that "Compared with the normal nighttime ozone concentrations (an average of 36.6 ppbv), the magnitudes of surface ozone surge due to stratospheric intrusions were approximately 40-50 ppbv". If the "normal nighttime ozone concentrations" were already shown in Figure 4, i.e., with the average diurnal pattern, readers would easily see the "departure" of ozone/CO from their "normal nighttime concentration". Also, I suggest only including the "hour" in the X-axis should be informative enough.

Thank you for your points. Figure 4 shows the high-frequency observations of ozone and CO during the night of 31 July 2021, which are more valuable and evident to track the exact time when stratospheric ozone-rich and CO-poor air reached the ground. For the sake of consistency, we kept the original labels of X-axis.

(8) Figure 5, what do the positive/negative vertical velocities represent? Positive values (blue) are winds going down to the surface? Or the other way around? Please clarify in the figure caption.

Yes, the positive vertical velocity (omega) in the unit of Pa s^{-1} represents downward air motions and the negative one represents the upward air motions. Thanks for your suggestion. We now add the information in the figure caption.

(9) In Figure 7, similarly, I don't understand why an average level of ozone between surface and 700hPa is used as a baseline. Shouldn't the baseline be the 10-day average vertical profile? With the current figure, the readers must be puzzled why the surface ozone concentrations on July 31 and Aug 1 are lower than the average, while the other sections repeatedly show that the surface ozone concentrations in NCP are larger than the average.

According to previous studies, only a few percent of the ozone at about 700 hPa could be clearly attributed to direct stratospheric intrusions (Elbern et al., 1997; Stohl et al., 2000). For this reason, the 10-day dewpoint depressions (humidity information; Fig. 6) and ozone concentrations below 700 hPa are averaged as the baseline to track the descending stratospheric dry and ozone-rich air from upper levels. Since the ozone baseline here is an average between the surface and 700 hPa, as a result, the ozone concentration at the surface level was lower than the baseline value.

Elbern, H., J. Kowol, R. Sladkovic, and A. Ebel, Deep stratospheric intrusions: A statistical assessment with model guided analyses, Atmos. Environ., 31, 3207 – 3226, 1997.

Stohl, A., et al., The influence of stratospheric intrusions on alpine ozone concentrations, Atmos. Environ., 34, 1323 – 1354, 2000.

(10) Line 360-364, this information should be moved before mentioning Bow-echoes.

Thank you for this valuable suggestion. The description of bow-echo MCSs was moved to Line 358-363.

(11) Figure 8, why not show the ozone data at all sites at all times and use a colour scale that covers 10 to 100 ppbv? With the current layout, there is no way to tell how much ozone is increased from 2100LST to 0100LST at stations like JN/BZ. It could just be 1 ppbv of increase (if ozone at JN/BZ were 79 ppbv at 2100LST and 80 ppbv at 0100LST) or >80 ppbv of increase (if ozone were <1 ppbv at 2100LST and >80ppbv at 0100LST).

Sorry for this. We have tried to plot all the ozone observations ranging from 10 to 120 ppbv. However, the radar reflectivity field is covered when more ozone data are mapped, and hence it is hard to tell the fine-scale structure of MCSs. For this reason, only ozone observations with high concentrations (80-110 ppbv) are shown in Figure 8, and stations with ozone concentrations less than 80 ppbv are not displayed for clearness.

Specific comment:

4. line 37, this line reads like both “water vapour” and “carbon monoxide” are primarily emitted from combustion processes, while only CO is. Consider revising it.

Thank you for your suggestion, the sentence has been modified.

5. Line 75, what problems “require in-depth investigation”?

Thank you, we have modified the sentence.

6. Line 199, is this 36.6 ppbv calculated in this study or from a previous study?

The nighttime averaged ozone concentration in the 2021 summer over NCP was calculated based on observations. We have added this information in this revision.

7. Line 228-230, this sentence sounds important. Any figures/data to support it?

Yes, the spatial coverage can be inferred from the cities with increasing ozone and decreasing CO as shown in Figure 2 and Figure 3. Regions associated with high nighttime ozone concentrations due to stratospheric intrusion are also evident in Figure 8.

8. Line 237, “filed” should be “field”. I have spotted a few more typos. Please check through the manuscript.

Thank you for pointing this out. We have corrected typos throughout the manuscript.

9. Line 239, it is >30% increase from 45 to 60 ppbv. I would not call it “slightly higher”.

Thank you for pointing this out, we have modified the sentence.

10. Line 250-251, an increase in ozone from ~36 ppbv to ~80 ppbv is a large enhancement, but this level of ozone (80 ppbv) should be very common in this region. I suggest toning down the phrase “great threats”.

Thank you for pointing this out, we have modified the sentence.

11. Line 262, somehow the authors missed “anthropogenic emission”?

Thank you. We added “anthropogenic emissions” in the sentence.

12. Line 266-267, this is probably true, but it will be better if the evidence is presented.

Thank you. Here we just provide the results of previous studies concerning the convection and STE.

13. Line 271, “indicate” should be “indicated”.

Corrected in Line 274.

14. Line 417, “the analysed at detail” should be “be analysed in detail”.

Corrected in Line 427.

Reference:

Meng, K., Zhao, T., Xu, X., Hu, Y., Zhao, Y., Zhang, L., Pang, Y., Ma, X., Bai, Y., Zhao, Y. and Zhen, S., 2022. Anomalous surface O_3 changes in North China Plain during the northwestward movement of a landing typhoon. Science of The Total Environment, p.153196. http://dx.doi.org/10.1016/j.scitotenv.2022.153196

Thank you for providing this reference, which was added in the manuscript.