#Reviewer 4

This paper discussed the downward transport of stratospheric ozone to the troposphere as well as down to the surface through a combined effect of a dying typhoon In-fa and shallow local mesoscale convective system (MCS). They analyzed the ozone and CO concentration, meteorological reanalysis data, radiosonde data, and FLEXPART-WRF simulation. The downward transport of stratospheric ozone-rich air to the surface will degrade surface air quality and affect human health. Overall, the paper is good. It studied an important topic, used various observations. However, it still has some major weak points.

We thank the reviewer for the positive comments and very careful reading of our article. The corrections are addressed below.

General comments:

1. Because the downward transport was caused by typhoon In-fa, it would be nice to have a brief introduction of typhoon In-fa in section 2. Please include a plot showing the development of the typhoon In-fa (e.g., radar reflectivity for different times), and a plot showing the path of the typhoon In-fa. This will help the reader to understand the discussion of the second part.

The development of typhoon In-fa was described in Line 280-298; and the track information of In-fa was provided in Fig. 5a (magenta cross symbols). Thank you for your suggestion, we downloaded the radar reflectivity maps of In-fa from 27-30 July 2021 as shown in Fig. S5 in the supplementary file.

2. Lightning-generated NOx could also increase downwind ozone level. The paper did not prove that the ozone increase is not caused by LNOx generated by previous storms.

Yes, the precursors (NOx and VOCs) of ozone can significantly influence the ozone concentrations, however, as stated in the manuscript, this ozone surge event occurred in the nighttime when photochemical reactions ceased. In the meantime, the storm was weakly electrified and hence showed low lightning flash rates (Line 383).

3. In the paper, they calculate the 10-day mean O3/CO as the baseline. However, the 10-day mean included the days affected by typhoon In-fa. Therefore, is hard to tell what's the normal condition. It might be better to use the 10-day mean before the typhoon period as the baseline.

Thank you for this suggestion. We calculated the 10-day mean values of ozone and CO covering the typhoon and post-typhoon period in order to show the "weak" and "strong" phases of ozone more clearly under the influence of In-fa.

4. In this paper, they run WRF with tracer instead of using WRF-Chem. However, LNOx and other ozone precursors could also affect the results. Please explain why you choose not to use WRF-Chem or other chemistry models. The ozone production is not significant in the first few hours, however, previous studies found that there would be a great ozone increase in the downwind side on the next day. If you insist to use WRF with tracers, you need to convince the reader that your results would not be affected by any ozone chemistry reactions.

Thank you for pointing this out. Because this ozone surge event exactly occurred at night when sunshine was not available and hence photochemical reactions ceased, we focused on the dynamical transport of ozone (stratospheric air here) using the WRF model with tracers. To better resolve the vertical structure of the storm, the vertical spacing was increased with a resolution of ~200 m.

Specific comments:

Line 44, here are some references for deep convective transport of surface pollution and ozone precursors to upper troposphere:

Dickerson, R. R., Huffman, G. J., Luke, W. T., Nunnermacker, L. J., Pickering, K. E., Leslie, A. C. D., Lindsey, C. G., Slinn, W. G. N., Kelly, T. J., Daum, P. H., Delany, A. C., Greenberg, J. P., Zimmerman, P. R., Boatman, J. G., Ray, J. D., and Stedman, D. H. (1987). Thunderstorms: an important mechanism in the transport of air pollutants, Science, 235:460-465.

Pickering, K.E., Thompson, A.M., Scala, J.R., Tao, W.-K., Simpson, J., and Garstang, M. (1991). Photochemical ozone production in tropical squall line convection during NASA Global Tropospheric Experiment/Amazon Boundary Layer Experiment 2A. J. Geophys. Res. 96, 3099–3114.

Pickering, K.E., Thompson, A.M., Scala, J.R., Tao, W.-K., and Simpson, J. (1992c). Ozone production potential following convective redistribution of biomass burning emissions. J Atmos Chem 14, 297–313.

Li, Y., Pickering, K.E., Allen, D.J., Barth, M.C., Bela, M.M., Cummings, K.A., Carey, L.D., et al. (2017). Evaluation of deep convective transport in storms from different convective regimes during the DC3 field campaign using WRF-Chem with lightning data assimilation. J. Geophys. Res. Atmos. 122, 2017JD026461.

Thank you, the above references have been added in the manuscript.

Line 110, it would be nice to have a brief introduction of typhoon In-fa in section 2. Please include a plot showing the development of the typhoon In-fa (e.g., radar reflectivity for different times), and a plot showing the path of the typhoon In-fa. This will help the reader to understand the discussion of the second part.

Thank you, more information of typhoon In-fa has been added in the manuscript and supplementary file (Fig. S5).

Line 166, please include the reference for WRF.

Thank you. The reference for WRF was added in the manuscript.

Skamarock, W.C., Klemp, J.B., Dudhia, J., Gill, D.O., Barker, D.M., G Duda, M., Huang, X.-Y., Wang, W., and Powers, J.G.: A description of the advanced research WRF version 3. NCAR Tech. Note NCAR/TN-475þSTR, p. 113. https://doi.org/10.5065/D68S4MVH, 2008.

Line 167, please add a figure showing the location of each domain in supporting information.

Thank you for this suggestion. The simulation domains were shown in Fig. S1.

Line 185, why do you choose WRF instead of WRF-Chem? See general comments 4.

Thank you, because this nighttime ozone surge case occurred when photochemical reactions ceased, we used WRF with tracers to study the dynamical transport pathways of stratospheric ozone-rich air.

Figure 2, see general comments 3.

Thank you, the averaged values of ozone and CO under the influence of typhoon In-fa were calculated and used as the baseline in order to show the “weak” and “strong” phase of ozone for different times

Figure 2, please add a map showing the storm location during the ozone surge period.

Thank you, the storm location during the ozone surge period was provided in Fig. 8 in the manuscript.

Line 226, CO is also an important tracer for deep convective transport. Please include references here. “CO is offen….(add references)”

Thank you. The reference for CO was added in the manuscript.

Pochanart, P., Akimoto, H., Kajii, Y., and Sukasem, P.: Carbon monoxide, regional-scale, and biomass burning in tropical continental Southeast Asia: Observations in rural Thailand. J. Geophys. Res.-Atmos., 108, 4552, https://doi.org/10.1029/2002JD003360, 2003.

Lin, Y.-C., Hsu, S.-C., Lin, C.-Y., Lin, S.-H., Huang, Y.-T., Chang, Y., and Zhang,

Y.-L.: Enhancements of airborne particulate arsenic over the subtropical free troposphere: impact of southern Asian biomass burning, Atmos. Chem. Phys., 18, 13865–13879, https://doi.org/10.5194/acp-18-13865-2018, 2018.

Line 250, please mention the ozone exceedance level, and compare the observed ozone level to the ozone exceedance level. Otherwise, you cannot conclude that “which can pose great threats to human health…”

Thank you, the Chinese National Ambient Air Quality Standard for ozone exceedance level is 82 ppbv (Li et al., 2020). We added this exceedance level in the manuscript.

Li, K., Jacob, D. J., Shen, L., Lu, X., De Smedt, I., and Liao, H.: Increases in surface ozone pollution in China from 2013 to 2019: anthropogenic and meteorological influences, Atmos. Chem. Phys., 20, 11423–11433, https://doi.org/10.5194/acp-20-11423-2020, 2020.

Line 268, please explain more about “no influence from ozone precursors from biomass burning or LNOx”. See general comments 2.

Thank you. Because the photochemical reactions had ceased when the nighttime ozone surge event occurred, and there were synthetic decreases of CO concentrations, suggesting that there were few influences from biomass burning. In terms of lightning activities, the storm was weakly electrified and produce low lightning flash rate. A total of 362 cloud-to-ground lightning flashes were detected from 21:00 LST on 31 July to 06:00 LST on 1 August 2021 within 50-km radius of Zhanhua station. For the reason above, we concluded that there was no significant influence from ozone precursors from biomass burning or LNOx.

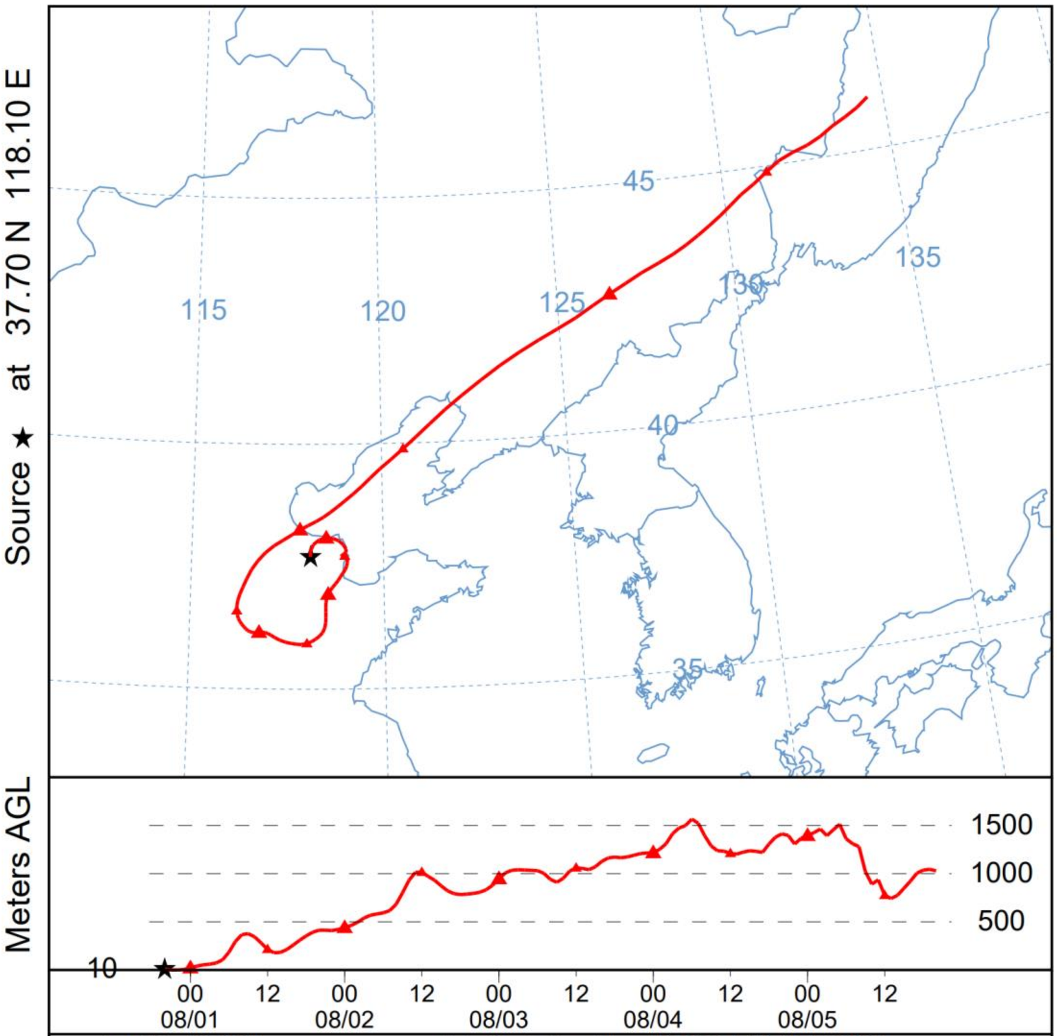
Figure 5, please label time in each plot.

Thank you for pointing this out. The time label is expressed as “Month/Day/Hour” in the bottom-right corner of each panel.

Line 400, could you add a forward trajectory experiment of stratosphere tracers?

Thank you for this suggestion. Given the computational cost of high-resolution model output, we calculated the 5-day forward trajectory of stratospheric air using the NOAA HYSPLIT Model. The location of trajectory was set to Binzhou (37.7 ^{o}N, 118.1^{o}E, the black star symbol in the figure) at an altitude of 10 m at 04:00 LST on 1 August 2021. The forward trajectory from HYSPLIT shows that the stratospheric air that had reached the ground remained in the planetary boundary layer (<1500 m) for the next five days, suggesting the important consequences of such an ozone enhancement with stratospheric origin.

NOAA HYSPLIT MODEL
Forward trajectory starting at 2000 UTC 31 Jul 21
GFSQ Meteorological Data



Job ID: 164681 Job Start: Tue May 10 08:21:50 UTC 2022
Source 1 lat.: 37.700000 lon.: 118.100000 height: 10 m AGL

Trajectory Direction: Forward Duration: 120 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 31 Jul 2021 - GFS0p25