#Reviewer 2

General comment:

This is an interesting case study of significant stratospheric ozone transport down to the Earth's surface by a dying typhoon, affecting local and regional air quality. Several observational data and modeling tools are applied to analyse/confirm the downward transport of ozone with stratospheric origin. Overall, this is a well-designed study which is relatively easy to follow. Such events of direct ozone transport have implications for air quality, contributing in ozone standards exceedances. The paper fits well within the scope of ACP and I recommend publication after the following comments are addressed.

We thank for the reviewer's helpful comments. We have revised the manuscript thoroughly according to the comments and the manuscript has been improved substantially. The point-to-point responses are listed below.

Comments:

The only thing I found missing in the analysis are humidity measurements near the surface from ground-based meteorological stations. This would offer the temporal variability of humidity near the surface, likely supporting the case that the observed ozone increases are of stratospheric origin. Is this feasible?

Yes, humidity observations near the surface would provide extra evidences for the stratospheric intrusion. However, it is a pity that we have only limited humidity data with coarse temporal resolution from ground-based meteorological stations to explicitly track the moisture variations.

L41-42: A more scientific definition of the tropopause is rather necessary here.

Thank you, we have modified the sentence.

L59: Some additional references of direct SI impact on surface ozone concentrations are needed here like Akritidis et al. (2010), Dreessen (2017), and Knowland et al. (2017).

Thank you for providing these references. These references are added in this revision.

L60: Meul et al. (2018) and Akritidis et al. (2019) also suggested an increase of STT in a future climate.

Thank you for providing these references. We have added these references in this revision.

L74-76: Maybe some references are needed here. Which are the fundamental problems requiring in-depth investigation?

Thank you for your suggestion, some references were added in the manuscript. We have modified the sentence.

L78-79: “the stratospheric ozone-rich airmass was transported downward to the surface”. This is Introduction and such statements are not yet supported. I suggest removing or rephrase.

Thank you, we have modified the sentence.

L137-138: “along with ground-based automatic weather station observations”: Which exactly? Do you mean the radar data? If not, are these shown anywhere in the paper?

Sorry for this mistake, we have modified the expression.

L298: Why is the PV = 2.5 pvu isosurface selected for tropopause representations? Usually, 2 and 1.5 pvu are used. A reference/rationale for that selection would be helpful.

Thank you for point out this problem. Values of potential vorticity ranging between 1-4 PVU can be found in the literature. For example, Hoerling et al. (1991) chose a 3.5-PVU isoline for their tropopause analysis because it statistically agreed with the thermal tropopause. In the study of Maddox and Mullendore (2018), they found a 2.89-PVU threshold was best fit the constant-altitude tropopause. In this study, we applied the 2.5-PVU isosurface to represent the dynamical tropopause following Wirth (2003). The reference is added in the manuscript.

Wirth, V.: Static stability in the extratropical tropopause region, J. Atmos. Sci., 60, 1395–1409, https://doi.org/10.1175/1520-0469(2003)060<1395:SSITET>2.0.CO;2, 2003.

Figure 4: Vertical lines delimiting the O3 increase and CO decrease (similar to Figure 3) would be helpful here.

Thank you for this suggestion, the lines were added in Figure 4.

Figure 7: Here the 10-day average "between the surface and 700 hPa" is used as baseline for the O_3 profiles. What is the rationale behind this selection (between the surface and 700 hPa)? As O_3 increases in general with height, I think it is likely that the positive (red) departures in the troposphere are partially normal, masking the STT effect.

Thank you for pointing out this problem. 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 to represent the features of low-level air. And the averaged values of dewpoint depressions and ozone concentrations were used as the baseline to track the descending stratospheric dry and ozone-rich air from upper levels. Through day-to-day comparisons, it is clearly that large positive departures extended from upper troposphere to the lower altitudes (Fig. 7a-c).

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.

L407-408: "when the stratospheric airmass had reached the surface". Where does this arise from? If it's based on a Figure, please include it in parentheses e.g. (see Fig. 2)

Thank you for pointing this out. Based on Fig. 2 and Fig. 4, it is confirmed that the stratospheric ozone-rich air had reached the surface. We have modified the sentences in Line 416.

Figure 11: What do the magenta contour line labels describe? Is this percentage (%) of total number release? Please include this information in the respective caption.

Sorry for this, the magenta contour lines represent the number of tracers. We have added more descriptions about the contour lines in the caption (Line 461).

Technical comments

L16: "on 31 July 1 to 6:00" delete "1"

Thank you. Corrected and checked throughout the manuscript.

L25: Please move FLEXPART and WRF full names in the previous line where are referred.

Thank you. We have modified the sentence in Line 23-25.

L34: and the troposphere

Corrected.

L34: atmospheric composition

Corrected.

L56: STT usually stands for Stratosphere-to-Troposphere Transport which is not the case here. Please remove STT or change the phrase.

Removed.

L76: origin

Corrected throughout the paper.

L80: Compare with -> Compared to

Thank you. Corrected.

L87: Since here you are referring to a specific study I suggest to directly mention it. “Chen et al. (2021) evaluating the impacts of typhoons on tropospheric ozone showed..”.

Thank you for your suggestion. We have modified the sentence in Line 87-88.

L134: and they show -> showing

Modified.

L151: the stratospheric dryness -> dry stratospheric air

Modified.

L199: Please include nighttime definition (hour range).

Thank you for your suggestion, the nighttime is defined as 19:00-06:00 LST and has been added in the manuscript (Line 198).

L228: “confirms” is somehow strong here, I suggest “supports the case”

Corrected in the manuscript (Line 227), and thank you for this valuable suggestion.

L357: lasting->lasted

Corrected.

L458: “occurring at nigh”. As this is the beginning of the conclusions, the date of occurrence should be also stated.

Thank you for this valuable suggestion, we have added the date in the manuscript (Line 467).

L459-460: “while the impacts of stratospheric intrusions on surface ozone are relatively less studied”. This is somehow not connected to the previous part of the sentence, thus, I suggest to split in two sentences.

Thank you for your suggestion, we have modified the sentence (Line 468).

L512-513: “which underscores the necessity of considering these processes into the global model of atmospheric chemistry.” This phrase is somehow strange. What do you mean by global model of atmospheric chemistry? Please rephrase.

Sorry for this, we have modified the sentence (Line 524).

References

Akritidis, D., Zanis, P., Pytharoulis, I. et al. A deep stratospheric intrusion event down to the earth’s surface of the megacity of Athens. Meteorol Atmos Phys 109, 9–18 (2010). https://doi.org/10.1007/s00703-010-0096-6

Akritidis, D., Pozzer, A., and Zanis, P.: On the impact of future climate change on tropopause folds and tropospheric ozone, Atmos. Chem. Phys., 19, 14387–14401, https://doi.org/10.5194/acp-19-14387-2019, 2019.

Dreessen, J. (2019). A Sea Level Stratospheric Ozone Intrusion Event Induced within a Thunderstorm Gust Front, Bulletin of the American Meteorological Society, 100(7), 1259-1275.

Knowland, K. E., Ott, L. E., Duncan, B. N., & Wargan, K. (2017). Stratospheric intrusion-influenced ozone air quality exceedances investigated in the NASA MERRA-2 reanalysis. Geophysical Research Letters, 44, 10,691– 10,701. https://doi.org/10.1002/2017GL074532

Meul, S., Langematz, U., Kröger, P., Oberländer-Hayn, S., and Jöckel, P.: Future changes in the stratosphere-to-troposphere ozone mass flux and the contribution from climate change and ozone recovery, Atmos. Chem. Phys., 18, 7721–7738, https://doi.org/10.5194/acp-18-7721-2018, 2018.

Thank you for providing these references. We have added the references in this revision.