April 8, 2025

Author Comments (egusphere-2024-3719)

Manuscript title: Hemispheric differences in ozone across the stratosphere-troposphere exchange region

We have carefully read the referee and community comments. We greatly appreciate their quality and constructiveness. Accordingly, we have addressed each comment and incorporated the suggested changes in a new version of the manuscript. The referee and community comment revisions are addressed below.

Referee Comment (RC1)

General comments:

The paper is well written, the data analysis is thorough and detailed. However, I sometimes miss the more global background a bit. Therefore, a justification why it is important to study hemispheric differences in UTLS ozone, and possible causes and consequences should be further elaborated on.

The major shortcoming of the study is the very limited spatial extent of the study region in the southern hemisphere, due to the availability of measurements, so that the representativeness of the hemispheric differences (and their longitudinal dependence) is hard to assess. In this context, I found it very surprising that the authors did not consider to include also the Lauder (45°S) ozonesonde dataset in their analysis, next to the Ushuaia ozonesonde dataset, which is just at the border of the defined zonal band (45°-60°S). The authors did mention the Lauder ozonesonde dataset at Line 69. Some explanation for not including this dataset is missing here.

Also, the time period for the available measurements used for the NH (IAGOS: 2011, 2018-2022) does not fully align with the time periods used for the SH (2019: SouthTRAC, 2008-2018: WOUDC). Why not using the entire IAGOS dataset from 2008-2022 for the NH and also using the WOUDC data for Ushuaia 2019-2022? Wouldn't there be an impact of a possible temporal mismatch between the NH and SH UTLS ozone observations that are compared? This could be investigated with the CAMSRA, if you would take full advantage of its entire temporal extent (see also in the specific comments). And why did you not compare the 2019 UTLS ozone observations between SouthTRAC and Ushuaia?

Answer: Although we will address the above-mentioned aspects in the specific comments, at this point, we indicate that we extended the analysis period and included two additional ozonesondes launched within the latitudinal band of interest. In summary:

- IAGOS: 2002-2022
- Ozonsonde launched from Lauder and Macquarie Island: 2002-2022
- CAMSRA: 2003-2022

I think section 2 should be better organized as well and a distinction should be made between 2. Data (section 2, now subsections 2.2, 2.3, 2.4, 2.5) and 3. Methodology (now subsections 2.1 and 2.5). Currently, you are presenting and mentioning the geographical (horizontal and vertical) extent of the observations, before presenting the observations themselves. To me, this is not a very logical order.

Answer: Thanks for suggesting this improvement. Now, we have two sections, one for data and the other for the methodology:

2. Data
2.1 SouthTRAC data
2.2 Ozonesonde data
2.3 IAGOS data
2.4 CAMS & ERA5 reanalysis
3. Method
3.1 Study period & UTLS definition
3.2 High and low ozone depletion years definition
3.3 Stratospheric character determination

At several locations, some additional clarifications are needed, which are summed up in the specific comments.

Specific comments:

Lines 80-85: I assume much more literature is available and much more key findings regarding the hemispheric UTLS ozone differences. Please add those here.

Answer: We added more literature related to SSWs, e.g.:

- *Charlton, A. J. and Polvani, L. M.: A new look at stratospheric sudden warmings. Part I: Climatology and modeling benchmarks, J Clim, 20, https://doi.org/10.1175/JCLI3996.1, 2007.*
- *Lim, E. P., Hendon, H. H., Butler, A. H., Thompson, D. W. J., Lawrence, Z. D., Scaife, A. A., Shepherd, T. G., Polichtchouk, I., Nakamura, H., Kobayashi, C., Comer, R., Coy, L., Dowdy, A., Garreaud, R. D., Newman, P. A., and Wang, G.: The 2019 southern hemisphere stratospheric polar vortex weakening and its impacts, https://doi.org/10.1175/BAMS-D-20-0112.1, 2021.*
- *Rao, J., Garfinkel, C. I., White, I. P., and Schwartz, C.: The Southern Hemisphere Minor Sudden Stratospheric Warming in September 2019 and its Predictions in S2S Models, Journal of Geophysical Research: Atmospheres, 125, https://doi.org/10.1029/2020JD032723, 2020.*

And also key papers addressing the importance of ozone changes in UTLS, e.g:

- *Millán, L. F., Hoor, P., Hegglin, M. I., Manney, G. L., Boenisch, H., Jeffery, P., Kunkel, D., Petropavlovskikh, I., Ye, H., Leblanc, T., and Walker, K.: Exploring ozone variability in the upper troposphere and lower stratosphere using dynamical coordinates, Atmos. Chem. Phys., 24, 7927–7959, https://doi.org/10.5194/acp-24-7927-2024, 2024.*
- *Neu, J. L., Hegglin, M. I., Tegtmeier, S., Bourassa, A., Degenstein, D., Froidevaux, L., Fuller, R., Funke, B., Gille, J., Jones, A., Rozanov, A., Toohey, M., Von Clarmann, T., Walker, K. A., and Worden, J. R.: The SPARC data initiative: Comparison of upper troposphere/lower stratosphere ozone climatologies from limb-viewing instruments and the nadir-viewing tropospheric emission spectrometer, J Geophys Res, 119, https://doi.org/10.1002/2013JD020822, 2014.*

On the other hand, the time period extension (from 2002) and more long-term ozonesondes (159º and 170ºE) added to the analysis allow us to improve the context to articulate a broader discussion. Also, at the beginning of the abstract and the end of the introduction, we added some lines to describe the motivation of the research:

Abstract: "*Ozone changes in the upper troposphere-lower stratosphere (UTLS) resulting from dynamical and chemical processes strongly affect the atmosphere's radiative forcing. This study analyzed intra- and interhemispheric ozone differences in the UTLS within the 45-60° latitude band, distinguishing between years disrupted by sudden stratospheric warming (SSW) events from 2002 to 2022…*"

Introduction: "*Ozone in the UTLS is highly variable, driven by a complex interplay of dynamical and chemical processes (Millán et al., 2024; Bourgeois et al., 2020; Neu et al., 2014; Riese et al., 2012). In this context, SSW events represent a diminished ozone depletion scenario, which, combined with the highly resolved profiles obtained during the SouthTRAC campaign, provides a unique and realistic framework for assessing ozone changes. In this study, we leverage the increased ozone abundance under low-depletion conditions derived from SSW events to determine the effect on the ozone mixing ratio in UTLS of both hemispheres. This comparative analysis is based on stratospheric and tropospheric chemical traces measured during the SouthTRAC mission, by IAGOS commercial aircraft and by from ozonesondes, focusing on the 45-60° latitude band. Spatial coverage is further enhanced using the Copernicus Atmosphere Monitoring Service reanalysis (CAMSRA), which is compared against in situ measurement.*"

Line 105: the selection criterion for high-depletion and low-depletion years ("disrupted by SSW") should be further specified. Did you mean that any occurrence of a SSW (where? When?) is enough to call a year a low ozone depletion year? An objective criterion for "disrupted" is needed as well. Any ozone concentrations threshold used?

Answer: We added a new section (3.2) to describe how we distinguished low and high depletion years. Also, in Table 2, we summarized the high and low depletion years for each hemisphere:

"3.2 High and low ozone depletion years definition

We distinguished low ozone depletion years from high ozone depletion years according to the occurrence of SSW events. Therefore, we applied the definition proposed by (Charlton and Polvani, 2007) to detect major SSW, which is based on determining the reversal of the daily-mean, zonal-mean zonal winds from westerly to easterly at 60ºN and 10 hPa from November to April. ***Table 2*** *shows the first day (central date) on which the daily zonal mean zonal wind at 10 hPa and 60°N changed from westerly to easterly between November and March. During the detection procedure, we required 20 consecutive days with westerly winds before identifying another event. We excluded cases with easterly zonal winds that did not return to westerly for at least 10 consecutive days before 30 April. In the SH, the shift from westerly to easterly is considered between July and October, and we excluded the cases when the wind did not return to westerly by 30 November."*

Table 1: see my general comment on a possible temporal mismatch of the NH and SH UTLS ozone observations.

Answer: We followed the recommendation to increase the analysis period. Table 1 describes the new periods and availability, which start in 2002.

Table 1: Summary of data used. The columns detail dataset sources, spatial coverage, temporal periods, the number of flights in the period and the number of measurements for each variable (in ozonesondes is the number of interpolated measurements) between 200-300 hPa.

Data source	Hemisphere or site (lat., lon.)	Periods	No. flights or valid launches	Variable (No. measurements)
SouthTRAC	SH (45ºS-60ºS, 30ºW-85ºW)	4 Sep - 20 Nov 2019	16	Pressure: 43k O_3: 39k CO: 26k H_2O: 43k RH: 43k
WOUDC	1. Ushuaia (54.85ºS, 68.31ºW), 2. Lauder (45.04ºS, 169.68ºE), 3. Macquarie (54.50ºS, 158.95ºE)	1. 2008-2022 2. 2002-2022 3. 2002-2022	1. 141 2. 232 3. 203	1. Pressure: 7.1k O_3: 7.1k RH: 7.1k 2. Pressure: 12k O_3: 12k RH: 12k 3. Pressure: 11K O_3: 11k RH: 11k
IAGOS	NH (45°N-60°N)	2002-2022	6,315	Pressure: 16M O_3: 11M CO: 11M H_2O: 14M RH: 15M

Lines 142-145: it should be clearly mentioned here that you describe the RH measurements of the radiosonde to which the ozonesonde is coupled for data transmission and auxiliary meteorological measurements (air pressure, temperature, relative humidity, wind direction and speed).

Answer: Thank you for noticing this. We added: "*These ozonesondes were coupled with radiosondes, which measured pressure, temperature, RH, wind speed and wind direction.*"

Section 2.4: the IAGOS-CORE ozone measurements have not been described here.

Answer: Please check again because it is described: "*IAGOS-CORE provides ozone (and carbon monoxide) data using an ultraviolet (infrared) absorption spectrometer, with an accuracy, precision and time response of 2 nmol mol^{-1}, 2% and 4 s (5 nmol mol^{-1}, 5%, 30 s) respectively.*"

Lines 167-168: the RH measurements are done by the Vaisala radiosonde sensors, not by the ozonesonde. So replace "ozonesonde" with "radiosonde" here (and at other locations).

Answer: We appreciate noticing this, and we have changed this typo throughout the document.

Lines 179-180: "we reduced the number of pressure bins between 300 and 200 hPa to 5 bins": for CAMS or for the RS and IAGOS measurements? Not clear from the wording here.

Answer: We removed this sentence from the description of "CAMS reanalysis" and added in section 3.3: "*In **Figure 6**, the ozone boxplot is displayed in five pressure bins, determined by the five vertical levels available for CAMS in 300-200 hPa.*"

Lines 182-184: is there a priority given to those two principles (better: criteria)?

Answer: We reworded the following: "*In the following sections, we mainly used relative humidity to assign the stratospheric air character in the UTLS. At the same time, in some specific events, we also take advantage of the enhanced trace gases simultaneously measured, at high time resolution, on board HALO to further characterize the tropospheric or stratospheric origin of the air masses*."

Caption Fig. 2: add the LDY and HDY abbreviations after low and high-depletion years, as those abbreviations are used in the figure legend.

Answer: We made the change suggested.

Lines 203-204: "On this regard, we found CO mixing ratios up to 319 ppb between …": This cannot be seen from the plot. Not clear if the highest CO values without simultaneous O3 measurements are meant here. Clarify.

Answer: In the manuscript's new version, the period is longer for IAGOS data (2002-2022), so we have eliminated that sentence and left the main message: *Notice that some CO values are not included in NH because they were not simultaneously measured with ozone.*

Line 219: "tracers" instead of "traces"

Answer: We modify the text as suggested.

Line 226: replace "ozonesondes" with radiosondes.

Answer: We modify the text as suggested.

Fig 5: specify in the discussion around this figure which High-depletion and low-depleting years have been used for both the NH and SH in the CAMS calculations. In Section 2.6, I think you mention that the same years as for the observations (Table 1) are used, which would be a pity, given the longer available time range for CAMS. Could you provide the same figure as Fig. 5, but now for the entire available CAMS time range, to investigate the temporal impact on the comparisons? That would be a nice plus.

Answer: In the new section: 4.3 Outputs comparison based on in situ measurement and reanalysis, we introduce Figure 6 (before Fig. 5) with the following line: *Therefore, the motivation of this section is to compare the in situ measurements of ozone, filtered by 20% RH in the UTLS, with the values produced by the CAMS reanalysis over the entire longitudinal band within 45-60° latitude and for low and high depletion years indicated in **Table 2**, aiming to provide a spatially resolved perspective.*

Table 2 indicates the low and high depletion years utilized for Figures 5 and 6. Notice that by extending the period, we now have two SSW events in the SH.

Table 2: Study period considered for both hemispheres, subperiods and low ozone depletion years according to SSW definition.

Study period	Late winter-early spring (no. flights or launches)	Mid spring (no. flights or launches)	Low-depletion years (central date)
4 Mar - 20 May	4 - 31 Mar (456 flights)	1 Apr – 20 May (835 flights)	2002 (17 Feb), 2003 (18 Jan), 2004 (5 Jan), 2006 (21 Jan), 2007 (24 Feb), 2008 (22 Feb), 2009 (24 Jan), 2010 (24 Mar), 2013 (6 Jan), 2018 (12 Feb), 2019 (1 Jan) and 2021 (5 Jan)
4 Sep - 20 Nov	4 - 30 Sep (10 flights) (204 launches)	1 Oct - 20 Nov (6 flights) (372 launches)	2002 (25 Sep) and 2019[†] (15 Sep)

[†]: Central date determined when the zonal-mean zonal winds at 60°S and 10 hPa decrease to ≤ 20 m/s (Rao et al., 2020).

Fig 5: why do you have lower observation numbers in the pressure bins centered around 270 hPa?

Answer: The answer to this question involves aircraft companies decisions which uses specific flight altitudes in some regions. Particularly, in the North Atlantic region (50 - 20W, 50 - 60N), the 270 hPa bin was not sampled during March-May, contrary to the other regions.

Lines 280-283: "We delve into the apparent overestimation of ozone vertical gradient and medians obtained from the CAMS reanalysis across the entire longitudinal band of the Southern Hemisphere for high depletion years compared to ozonesonde measurements from the period 2008-2018 (Fig. 6)": I really do not have a clue where all these findings come from. Where do I see the apparent overestimation of ozone vertical gradient and medians? This can only be in Fig.5, I assume, but then late winter – early spring should be specified. But CAMS has not been used for the entire period 2008-2018? And how can you extend this finding for the ozone vertical gradient to the entire longitudinal band of the SH with Fig. 6? Not clear at all.

Answer: The new version of the manuscript benefits from the longer period and the ozonesondes launched at Lauder and Macquarie Island in the SH. These two changes eliminate the overestimation we faced with fewer data. In the new **section 4.3**, we described the new Figure 6 (previously Figure 5) in two terms: the better agreement between CAMS and the SouthTRAC period (the one with the higher frequency of measurement) and the improvement for the entire period when considering ozonesondes from Ushuaia, Lauder and Macquarie Island. We have selected some lines from the **section 3.3**:

***"Figure 6** also clearly illustrates the similarity between the ozone medians obtained from the CAMS reanalysis and SouthTRAC in the period with the highest number of flights, i.e., late winter-early spring, for pressures below 270 hPa."*

And:

"Hence, considering only ozonesondes, the enhancement for mid-spring was 17% (33 ± 10 nmol mol^{-1}) and for the entire period (SouthTRAC combined with ozonesondes) it was 24% (43 ± 13 nmol mol^{-1})."

Note we have also added a new **Figure B1** in Appendix B, which describes the Ozone boxplot without SouthTRAC data (also arising in the general comments by the reviewer)

Lines 286-288: should be clarified and quantified. How much is this slight improvement or worsening? At which pressure bins?

<u>Answer</u>: We eliminated those lines and Appendix C because, as indicated in the previous answer, we have improved our analysis with more ozonesonde and a longer period.

Fig. 6: Mark the SouthTRAC measurement region on the SH map here. Specify for which vertical range the ozone concentrations are shown.

<u>Answer</u>: In our opinion, it is a bit redundant to indicate the SouthTRAC measurement region again since it is described in **Figure 1**. On the other hand, we added in the caption of **Figure 7** (previously Fig. 6): *"...between 300-200 hPa"*.

Start the conclusions with some lines describing the SouthTRAC observations.

<u>Answer</u>: We added: *" The SouthTRAC mission represents an invaluable contribution to atmospheric chemistry research in the Southern Hemisphere. This aircraft campaign provided unique data recorded during a rare stratospheric sudden warming event in the Southern Hemisphere that produced profound effects on the chemical structure of the atmosphere, leveraged in this research as a proxy for a diminished ozone depletion scenario. The main conclusions of our research are listed below."*

Line 299: add 2019 after 12 Nov.

<u>Answer</u>: We modify the text as suggested.

Lines 299-302: this paragraph in the conclusions came a bit like a surprise, and I assume you are deepening a bit the analysis described in lines 215-221. If this finding is so important that an entire paragraph in the conclusions, with concentration numbers, is devoted to it, this would deserve also more details in the main manuscript as well (and the authors might consider moving the plot from the appendix to the main manuscript).

<u>Answer</u>: We agreed, so we moved the Figure to the main text (now **Figure 4**). We also added in the main text: "*Ultimately, the impact of emissions from the Australian bushfires in the UTLS may be interpreted as feedback initiated early in August-September 2019, which derived from the deceleration of the polar vortex in the middle stratosphere."*

Lines 310-314: isn't this a too strong conclusion, based on a very small number of statistics (i.e. low number of high-ozone depleting years in NH and low number of low-ozone depleting years in SH)? And in the NH you consider the entire latitudinal band, and only a small zone in the SH latitudinal band. You wrote this yourself in lines 321-322.

<u>Answer</u>: After the improvements included in this new version, we reworded this conclusion a bit: *"The interannual ozone variability in the NH UTLS (March-May) as a function of SSW events resulted in a 9% ozone enhancement (31 ± 11 nmol mol^{-1}) compared with years without SSW. This enhancement was nearly three times larger in the SH, reaching 24% (43 ± 13 nmol mol^{-1})."*

Referee Comment (RC2)

General Comments:

The text is polished and the figures are easy to digest and well-constructed. The SouthTRAC September-November 2019 aircraft data are serendipitous in that you can examine a rare Antarctic SSW and low depletion event with multiple in-situ chemical species (including some aged fire plumes). However, this paper is missing a lot of the broader context that would be provided by analysis of the Lauder (45S) and Macquarie Island (55S) ozonesonde records. Both of those records predate 2000 and would enable you to also examine the 2002 Antarctic SSW event, effectively doubling your SH low-depletion cases. Those two stations are on nearly the complete opposite side of the globe, adding longitudinal contrasts that are important, as you show in Figure 6. In fact, you might end up with different results with the inclusion of more SH data and a second SSW year in 2002. The SouthTRAC and Ushuaia ozone data are close to a local minimum in ozone according to Figures 1 and 6. In either case, you will add confidence to your results.

The study periods for the NH and SH should be aligned, something like 2002-2022 for both hemispheres, in my opinion. There should be plenty of IAGOS data in the NH to extend the study, and of course there is a dense network of ozonesonde stations in Europe and North America in your 45-60N band of interest. At the very least, why not align the study periods for both hemispheres and include the 2019 Ushuaia data?

Finally, I am curious to know who oversees the Ushuaia station and if they were offered co-authorship. Often, this recognition can help maintain a station's support.

In my assessment, this paper is not ready for publication and needs major revisions. The addition and analysis of more datasets, alignment of the study periods in both hemispheres, and a broader context and discussion of the impact of the differing STE ozone amounts between the two hemispheres will make this an important contribution.

Answer: We will address all the aspects mentioned above in the specific comments. However, at this point, we indicate that we extended the analysis period and included two additional ozonesondes launched within the latitudinal band of interest. This improvement allowed a broader discussion and added greater confidence to our results. In summary, the new periods analyzed are:

- IAGOS: 2002-2022
- Ozonsonde launched from Lauder and Macquarie Island: 2002-2022
- CAMSRA: 2003-2022

Specific comments:

Abstract lines 15-17: The answer to the question raised in the first sentence of the Abstract is well known and does not accurately capture what I think you are trying to demonstrate in this manuscript: Even during low depletion SH years, Southern Hemisphere UTLS ozone in STE events is far less than Northern Hemisphere high depletion years. The NH vs. SH lower stratospheric ozone differences in these latitude bands are obvious from the global ozonesonde network. See my quick analysis in Figure R1:

Abstract Line 26: "…the SSW event increased SH UTLS **<u>ozone</u>** by 37%..."

<u>Answer</u>: We appreciate this comment since it permits us to better focus our research. Accordingly, we removed those lines (15-17) and added: *"Ozone changes in the upper troposphere-lower stratosphere (UTLS) resulting from dynamical and chemical processes strongly affect the atmosphere's radiative forcing. This study analyzed intra- and interhemispheric ozone differences in the UTLS within the 45-60° latitude band, distinguishing between years disrupted by sudden stratospheric warming (SSW) events from 2002 to 2022."*

Regarding line 26, we emphasize that the work benefits greatly from the incorporation of the suggestions of both reviewers and therefore we have modified the last line of the summary due to the confidence gained: *"Notably, the SSW events (2002 and 2008) increased SH UTLS ozone by 24% (43 nmol mol^{-1}) compared to high depletion years, while in the NH, the increase was 9% (31 nmol mol^{-1})."*

Lines 82-83: Again, we can refer to Figure R1 to demonstrate that SH STE events will contain less ozone than NH STE events. There is simply less ozone in the SH mid-latitudes.

<u>Answer</u>: We thank you pointed this out. We think the following lines better reflect our research: *"Ozone in the UTLS is highly variable, driven by a complex interplay of dynamical and chemical processes (Millán et al., 2024; Bourgeois et al., 2020; (Neu et al., 2014); Riese et al., 2012). In this context, SSW events represent a diminished ozone depletion scenario, which, combined with the highly resolved profiles obtained during the SouthTRAC campaign, provides a unique and realistic framework for assessing ozone changes…"*

Line 97: It is contained in Table 1, but please state in the main text what time periods you are focusing on. Note also my concerns about mismatched time periods for the NH and SH.

<u>Answer</u>: We added the new period in the main text of Section 3.1: *"For comparison, IAGOS data from 2002 to 2022…"*

Line 104: "…interannual variability of both hemispheres…"

<u>Answer</u>: We modify the text as suggested.

Table 1: Why are the time periods examined not the same for NH and SH? Surely there are enough NH IAGOS data to make the analysis period for both hemispheres 2008-2022 or so? Also, extending back to 2002 will enable you to add a second SH SSW event. By adding Lauder and Macquarie Island ozonesonde data to the analysis, this can easily be accomplished for the Southern Hemisphere as well.

<u>Answer</u>: We extended the time back to 2002 and added Lauder and Macquarie Island. All this info is summarized in **Table 1**:

Table 1: Summary of data used. The columns detail dataset sources, spatial coverage, temporal periods, the number of flights in the period and the number of measurements for each variable (in ozonesondes is the number of interpolated measurements) between 200-300 hPa.

Data source	Hemisphere or site (lat., lon.)	Periods	No. flights or valid launches	Variable (No. measurements)
SouthTRAC	SH (45ºS-60ºS, 30ºW-85ºW)	4 Sep - 20 Nov 2019	16	Pressure: 43k O_3: 39k CO: 26k H_2O: 43k RH: 43k
WOUDC	4. Ushuaia (54.85ºS, 68.31ºW), 5. Lauder (45.04ºS, 169.68ºE), 6. Macquarie (54.50ºS, 158.95ºE)	4. 2008-2022 5. 2002-2022 6. 2002-2022	1. 141 2. 232 3. 203	4. Pressure: 7.1k O_3: 7.1k RH: 7.1k 5. Pressure: 12k O_3: 12k RH: 12k 6. Pressure: 11K O_3: 11k RH: 11k
IAGOS	NH (45°N-60°N)	2002-2022	6,315	Pressure: 16M O_3: 11M CO: 11M H_2O: 14M RH: 15M

Line 142 and other locations: RS92 radiosondes

Answer: We appreciate noticing this, and we have changed this typo throughout the document.

Lines 167 and 168: The RH measurements come from the Vaisala radiosondes, not the ozonesonde instrument

Answer: We modify the text as suggested.

Figure 2: It looks to me like the water vapor measurements are rounded to the nearest whole µmol mol-1, but are there really measurements of just 1 µmol mol-1?

Answer: Below 10% RH, the measurement uncertainty with the IAGOS-Core instruments becomes as high as the measured value itself. Also, the well-visible vertical H_2O lines are due to the fact that the IAGOS-Core H_2O mixing ratios are available as integers in the database. Given that, we preferred to remove water values below 7 ppmv as it does not affect the main message we want to convey.

Line 219: "tracers" not "traces"

Answer: We modify the text as suggested.

Line 226: Again, the RH measurements are from the radiosondes attached to the ozonesondes

Answer: We made the change suggested.

Line 232: "…applies to the 230-220 hPa bin…"

Answer: We made the change suggested

Figure 4: Why did you not include 2019 Ushuaia data in addition to SouthTRAC?

Answer: **Figure 5** (previously Fig. 4) includes the ozonesondes (indicated in **Table 1**) and SouthTRAC data. We also added in Appendix B the same analysis without SouthTRAC.

Line 242: Are these differences statistically significant? It might be difficult to draw conclusions based on the fairly limited data from single SH low depletion case in 2019.

Answer: Our analysis was substantially improved by extending the period analyzed. Line 241-242 was replaced by: "*In the NH, interannual ozone variability increased by 9% (31 ± 11 nmol mol^{-1}) compared with high depletion years. The changes in the subperiods late winter-early spring and mid-spring were similar, with 8% (26 ± 22 nmol mol^{-1}) and 10% (36 ± 12 nmol mol^{-1}), respectively.*"

Figure 6: Is the UTLS here also defined as 300-200 hPa? Please state clearly in the Figure 6 caption or plots

Answer: Yes, in **Figure 7** (previously **Fig. 6**) the pressure range is 300-200 hPa. Here is the caption: "*Figure 7: Ozone medians (nmol mol^{-1}) obtained from CAMS reanalysis filtered by RH lower less 20% at a resolution of 0.75° x 0.75° and between 300-200 hPa. The upper panel depicts the ozone median in UTLS of the northern hemisphere, separated into low and high depletion years (entire period), while the lower panel describes the same for the southern hemisphere. Note that the color scales are different in the NH and SH given the strong differences in ozone mixing ratios.*"

Figure 6 Caption: "…the same for the Southern Hemisphere"

Answer: We deleted the "s". We appreciate it.

Line 287-288: This sentence is unclear. Please rewrite.

Answer: We eliminated this sentence as well as Appendix C.

Lines 321-323: There is certainly a lack of in-situ ozone profile data in the SH, but you are not taking full advantage of what is available in this latitude band, including the Lauder and Macquarie Island ozonesonde datasets

Answer: We appreciate this suggestion, which let us improve our analysis substantially.

Community Comments (CC) by Keding Lu

General Comments:

The differences between the NH and SH mid-latitude UTLS ozone concentrations are of high interest for both the global radiative forcing and the global ozone budget studies. This paper provide timely analysis on a super valuable dataset on the mid-latitude SH UTLS measurements which could open a window of this demanding topic.

This manuscript has already received two thorough and critical reviews from two anonymous referees regarding the scope, scientific analysis and structure of the paper and I don't have anything to add. Nevertheless, I would agree with the two reviewers that the significant different sample size could be a point to further address of which in this case the two ozone sonde observations in SH could be considered.

Overall, for my responsibility, I just found no discrepancies between the conclusions and the findings of other papers submitted so far to the TOAR-II Community Special Issue.

Technical comments

1. The term 'ozone' is sometimes depicted as 'O_3' in both text and figures, maybe the authors can choose 'O_3' in all the figures while 'ozone' in the text, in addition, the font style might be synchronized too.

> **Answer**: We appreciate the comments and also agree with the reviewers on the benefits of increasing the analysis period and adding ozone soundings available at the SH.
>
> On the other hand, we used "ozone" instead of "O_3" throughout the text except in Tables and Figures. The same applies to carbon monoxide (instead of CO).