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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Stratospheric ozone intrusion events and their impacts on tropospheric ozone" *by* Jesse W. Greenslade et al.

Anonymous Referee #1

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The current study presents a method to identify stratosphere-to-troposphere transport (STT) events and estimate the associated ozone flux to the troposphere, based on ozonesonde profiles from three sites located in the Southern Hemisphere extratropics. Subsequently, the seasonality of STT events is determined, as well as the favorable synoptic conditions. Based on the stratospheric contribution to tropospheric ozone column estimated from the ozonesondes, the GEOS-Chem simulated tropospheric ozone columns are extrapolated to assess the stratospheric contribution over the Southern Ocean region. As the STT is of great importance for the tropospheric ozone budget and variability, and the number of relevant studies (both observational and modeling) for the examined region is limited, I find the topic of the paper within the scope of ACP. On the other side, there are several issues that need to be addressed before consideration for publication in ACP.

Major Comments:

1) Calculating the 99th percentile from the perturbation profiles over that layer (2 to 1 Km below the tropopause) is a fairly strict criterion. Wouldn't this threshold choice avoid the selection of deeper stratospheric intrusion events as "STT events"? Have you consider modifying this criterion, and include others (e.g. significant negative O3-relative humidity correlation values above a threshold) to minimize false STT detection?

2) The seasonality of STT events presented in Fig. 7 is not in line with the findings of Škerlak et al. (2015) for the examined region. How are your results (STT seasonality) compared with other modeling studies (Elbern et al., 1998; Sprenger et al., 2003)? Is there any evidence from other studies that STT frequency over the examined region exhibits a maximum during the austral summer (DJF) and not during the austral winter (JJA) when the jet stream is strongest over the broader region? Have you tried to detect STT events from the model results? I guess this is strongly depended to the vertical resolution of the model, but it would be very interesting to see how the observed and modeled STT seasonalities are compared.

3) To my understanding, using the seasonality of STT events from the three sites to extrapolate model results over the Southern Ocean region is a quite simplified and coarse approach, especially when considering the previous comment.

4) Overall, the presentation of the results can be further improved (please check my suggestions further below), as well as the writing of the manuscript.

Comments:

Škerlak et al. (2014) presented an STE climatology using the ERA-Interim data. This study is important not only for the introduction, as it describes the STT climatology for the SH, but for intercomparison of the results also. Similar climatologies can be found in the modeling studies of Roelofs and Lelieveld (1997) and James et al. (2003). Recently, Akritidis et al. (2016) explored the impact of stratospheric intrusions on tropospheric ozone and the associated stratospheric contribution over the eastern Mediterranean and the Middle East region, a task that is relevant with some of the purposes of this study.

Page 4, lines 3-4: Since the study is based on the ozonesondes launched from the three sites, it is important to present the location of the sites.

Page 4, line 22: "Figure 1 shows the monthly mean tropopause altitudes at ..", while in Fig. 1 caption is stated "Multi-year monthly median tropopause altitude ..". Is it the mean or the median? Please modify accordingly.

Page 5, Figure 1: a) The shadings used to describe the 10th and 90th percentiles are rather confusing. I suggest you replace the shadings with dashed lines (same color as the solid lines). b) Increase the range of the vertical axis to show the 10th percentile value for February. c) Is it the case that tropopause drops below 4 km (10th percentile) over Davis? What is the minimum tropopause height value over Davis during February?

Page 5, lines 5-6: "This seasonality at the high latitude sites is driven by a decrease in photochemical destruction under the reduced radiation conditions around polar night." Please include a reference or information about the NOx levels at these sites (if available) to justify this statement.

Page 6, line 14: It is important to know the vertical resolution of the GEOS-Chem model near the tropopause (although it can partially be seen from Fig. 13), as it is important for the tropopause height detection and the tropospheric ozone column calculations from the model results.

Page 7, lines 22-23: "The interpolated profiles. . .high frequency perturbations)." This is a rather brief description of the procedure. A more detailed description including a reference (if available) for the FT application would be necessary.

Page 7, lines 27-28: "We next use all the perturbation profiles at each site to calculate the 99th percentile perturbation value for the site". How exactly is this cut-off threshold

calculated? In Section 2.5, Page 9, the authors state that is calculated "between 2 km and 1 km below the tropopause". This information should be provided earlier in the manuscript, at the point that the 99th percentile threshold is initially mentioned (Section 2.3).

Page 8, Figure 3: Why the two panels have different units? Are the ozone units of the left panel "1e+12 molecules cm-3"? Please change accordingly the Figure and the Figure caption. mixing ratio -> number density

Page 9, lines 1-2: "For this reason all detected STT events found near smoke plumes are flagged". How is "near" defined?

In my opinion, Figures 4, 5 and 6 are more supportive-descriptive without adding anything new. Therefore, I suggest including them as a supplement. Moreover, Figures 5 and 6 can be merged into one.

Page 11, line 17: "We use the ERA-I 500 hPa data to subjectively classify the events based on their likely meteorological cause." Do the authors classify the events by visual inspection of the 500 hPa maps for every STT event date?

Page 11, lines 20-21: "The stratospheric polar vortex may create ozone folds without other sources of upper tropospheric turbulence". Please include a reference for the above statement.

Page 14, lines 16-20: "The seasonal distributions . . . first half of the year". To my understanding Fig. 7 and Fig. 8 are not quite similar. Moreover, comparing Fig. 8 with Fig. 7 where fire influences are also included is somehow unfair. The fact that ozonesondes are launched monthly at Davis from December to June is also the case for Fig. 7, where high STT frequencies are found for the respective period.

Page 16: How is the modeled tropospheric column ozone calculated? How is the tropopause defined in the GEOS-Chem results?

Page 17, lines 3-4: "Over Melbourne, ozone in the lower troposphere is well represented, but the model overestimates ozone from around 4 km to the tropopause". This is also seen for Macquarie and should be added to the discussion.

Page 19: "Figure 14 shows the mean fraction of total tropospheric column ozone (calculated from ozonesonde profiles) attributed to stratospheric ozone intrusions at each site, averaged over days when an STT event occurred." Please explain in more detail how is this fraction calculated.

Page 19: "to the entire Southern Ocean region, defined here as 35_ S-75_ S to encompass". What is the longitudinal range?

Page 20: Fig. 14 and Fig.15 can be merged into one.

Page 22: "If we we assume a fractional ozone impact due to each event STT event of I=35% based on their results". The 30-40% stratospheric contribution found by Terao et al. (2008) is seen only during spring and at 500 hPa. Therefore, assuming a 35% stratospheric contribution to the tropospheric column ozone seems a bit arbitrary.

Minor comments:

Page 1, line 4: seasonality -> seasonality of STT events

Page 1, line 9: 2.5 km, 3 km -> 2.5 km and 3 km

Page 1, line 14: these -> which

Page 2, line 2: .Despite lingering -> . Despite the lingering

Page 2, line 29: found STT -> found that STT

Page 2, line 31: challenging to accurately represent, and better model resolution -> challenging to be accurately represented, and finer model resolution

Page 3, line 6: low -> lower

Page 3, lines 14-16: Add references.

Page 3, line 16: characterized -> described

Page 8, line 12: transported -> transported over

Page 9, lines 22-23: (e.g., Sinha et al. (2004); Mari et al. (2008)). -> (e.g., Sinha et al., 2004; Mari et al., 2008). Please check the manuscript for similar instances.

Page 10, line 16: our three sites -> the three sites

Page 10, line 16: detected -> the detected

Page 11, line 23: profile -> vertical profile

Please replace all instances of "Brunt-Viäsälä" in the manuscript with "Brunt-Väisälä".

Page 19, Figure 13: dash -> red dash, please also provide information about the black dashes.

Page 22, line 9: If we we assume -> If we assume

Page 22, line 10: impact due to each event STT event -> impact due to each STT event

Page 22: empirically-derived threshholds -> empirically-derived thresholds

Page 22: Comparison with ERA-Interim reanalysis data -> Analysis of the ERA-Interim reanalysis data

Akritidis, D., Pozzer, A., Zanis, P., Tyrlis, E., Škerlak, B., Sprenger, M., and Lelieveld, J.: On the role of tropopause folds in summertime tropospheric ozone over the eastern Mediterranean and the Middle East, Atmos. Chem. Phys., 16, 14025-14039, doi:10.5194/acp-16-14025-2016, 2016.

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