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

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We thank the three reviewers for their detailed, thoughtful and insightful reviews which have improved the quality of our manuscript. In particular, we value their critique on our technique to determine a whole hemisphere flux, which has lead to an adjustment of our thresholds to incorporate more data and improve robustness in this data sparse Southern Hemisphere region. We write our detailed responses to each comment in blue text (and quoted text in magenta), directly below the specific reviewer comment.

Attachments include the updated manuscript, the author response document, the difference document generated by latexdiff, and a supplementary file.

Regards, Jesse Greenslade on behalf of all the coauthors.

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Discussion paper

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/acp-2016-1124/acp-2016-1124-AC1-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-1124, 2017.

Stratospheric ozone intrusion events and their impacts on tropospheric ozone in the Southern Hemisphere

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Abstract. Stratosphere-to-troposphere transport (STT) provides an important natural source of ozone to the upper troposphere, but the characteristics of STT events in the southern hemisphere extra-tropics and their contribution to the regional tropospheric ozone budget remain poorly constrained. Here, we develop a quantitative method to identify STT events from ozonesonde profiles. Using this method we estimate the seasonality of STT events and quantify the ozone transported across the tropopause over Davis (69° S, 2006-2013), Macquarie Island (54° S, 2004-2013), and Melbourne (38° S, 2004-2013). STT seasonality is determined by two distinct methods: a Fourier bandpass filter of the vertical ozone profile, and an analysis of the Brunt-Väisälä frequency. Using a bandpass filter on 7–9 years of ozone profiles from each site provides clear detection of STT events, with maximum occurrences during summer and minimum during winter above all three sites. The majority of tropospheric ozone enhancements from STT events occur within 2.5 km and 3 km of the tropopause at Davis, and Macquarie Island. Events are more spread out at Melbourne, occurring frequently up to 6 km from the tropopause. The mean fraction of total tropospheric ozone attributed to STT during STT events is ~ 1.0–3.5% at each site; however, during individual events over 10% of tropospheric ozone may be directly transported from the stratosphere. The cause of STTs is determined to be largely due to synoptic low pressure frontal systems, determined using coincident ERA-Interim reanalysis meteorological data. Ozone enhancements can also be caused by biomass burning plumes transported from Africa and South America, which are apparent during austral winter and spring, and are determined using satellite measurements of CO.

To provide regional context for the ozonesonde observations, we use the GEOS-Chem chemical transport model, which is too coarsely resolved to distinguish STT events but is able to accurately simulate the seasonal cycle of tropospheric ozone columns over the three southern hemisphere sites. Combining the ozonesonde-derived STT event characteristics with the simulated tropospheric ozone columns from GEOS-Chem, we estimate STT ozone flux near the three sites and see austral summer dominated yearly amounts of between 5.7 and 8.7×10^{17} molecules cm^{-2} a^{-1}.

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Fig. 1. Updated manuscript

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Fig. 2. latexdiff generated pdf of changes

Author's Response

We thank the three reviewers for their detailed, thoughtful and insightful reviews which have improved the quality of our manuscript. In particular, we value their critique on our technique to determine a whole hemisphere flux, which has lead to an adjustment of our thresholds to incorporate more data and improve robustness in this data sparse Southern Hemisphere region. We write our detailed responses to each comment in blue text (and quoted text in magenta), directly below the specific reviewer comment.

Anonymous Referee 1

Referee Notes:

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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"?
This should read as 2 km above the surface to 1 km below the tropopause since, as presently written, it implies a one kilometre range which would miss deeper intrusions. The text has been updated as follows on page 8, line 7: "... (2 km above the earth's surface to 1 km below the tropopause)." and on page 24, line 3: " … profiles between 2 km above the earth's surface and 1 km below the tropopause.".
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?
We investigated modifying this 99th percentile threshold in detail and found that lowering the limit to the 95th percentile is the optimal balance between including as many detections as possible while minimising false positives. Thus, we use the 95th percentile limit in our revised manuscript. Following an inspection of the parsed data, we found that lowering the threshold further resulted in too many clearly incorrect "O3 events" being incorporated into the results. We prefer to only include events which are clear STE events, which we accept could result in an underestimate of STE flux, than including data which are clearly spurious. Regarding use of humidity, this parameter is known to be biased low in the upper troposphere. To some extent this can be corrected for with the type of radiosonde (RS-90) which we used. However we have not performed this correction because it is difficult to apply uniformly across all sites due to seasonal variation in bias that is driven by the seasonal variation in tropopause temperature.

Fig. 3. Our responses to reviewers comments and suggestions

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Discussion paper

Supplementary: Stratospheric ozone intrusion events and their impacts on tropospheric ozone in the Southern Hemisphere

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Fig. 4. Supplementary document