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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Observations of ozone-poor air in the Tropical Tropopause Layer" *by* Richard Newton et al.

Richard Newton et al.

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We thank the reviewer for their careful and considered comments. We respond below to the specific comments made.

1. *The paper provides a somewhat limited review of the scientific literature of the TTL low-ozone problem.*
   A similar comment was provided by Anonymous Referee #1, and is addressed in the Response to Anonymous Referee #1.

2. *The paper would benefit from a more focussed detailing of what they are looking for in the various analyses they lay out and what the train of the argument will be. While this becomes clearer as you go along in the text, it would have been better*

if the reasoning had been presented at the outset.
   A new section in the introduction, labelled "Article overview" has been created to do this. The following text has been added to this section:

   > In section 2 we describe the instruments that were used on board the three aircraft to collect the measurements described in this article. Section 3 provides a brief overview of the CAST ozonesonde measurements from Manus, which were described in detail in Newton et al. [2016], that provided the first evidence of the occurrence of localized low ozone concentrations during the campaign.
   >
   > We then introduce the Global Hawk ozone profiles in section 4, concentrating on one flight that sampled well into the Southern Hemisphere from Guam in section 4.2—this flight produced further evidence of low-ozone concentrations, especially in the Southern Hemisphere portion of the flight. Within this section, we also discuss the uncertainties, and implications thereof, of the UCATS ozone instrument on board the Global Hawk, and how we approached the issue of noisiness in the UCATS dataset. This is followed by a brief discussion of the other ATTREX flights in section 4.3.
   >
   > Section 5 discusses the lower troposphere measurements that were made by the CAST and CONTRAST aircraft, providing information on boundary layer ozone concentrations that can be used to infer the origin of low ozone in the TTL. Section 6 shows a subset of the very short lived substances (VSLS) that were measured using Whole Air Samplers (WAS) on board all three aircraft, showing the composition differences between the VSLSs in low-ozone and high-ozone cases to infer that recently convected ozone-deficient air has a distinct chemical composition compared to high-ozone cases. (A supplementary section contains the full dataset of WAS VSLS chemical data.) Finally section

7 summarizes the findings of this article.

3. *Left unexplained is why the ascent segments appear in the figure to be coterminous. (Are the descents nearly instantaneous?)*
   Changes made to section 4 clarify this diagram, which has been modified to show exactly where the aircraft was below the tropopause. The following text has been added to the caption of figure 7 to ensure this confusion is not encountered by other readers.

   The grey line shows the flight path between profiles.

4. *Given that the UCATS ozone data are so central to the analysis in this section, indeed the whole paper, the rather severe shortcomings of UCATS ozone measurement mentioned in passing in Section 4 ought to have been discussed fully in Section 2 on instrumentation. Particularly concerning is the possible negative bias of up to 5 ppbv at low ozone concentrations. Given the possibility of such a substantial bias, the reader might fairly ask how much confidence can be placed in the hemispheric difference suggested in Fig. 7. I would suggest that the authors show at least an extended section of the ozone data in time series format to give the reader a better sense of the uncertainty in the averaged values.*
   We thank the referee for this comment which did indeed identify a serious omission in the original paper. We hope this is now rectified, in the form of a new section 4.2 discussing systematic errors in the UCATS data and an enlarged section 4.3 (old 4.2) discussing the random errors and why we choose the ascent sections of the flights rather than both ascent and descent in the colour line plots. Fig. 11 shows a time series of (averaged) data with error bars along RF05.

5. *Section 6 shows in Figure 17 some separation between profiles of Very Short-lived Substances originating in the marine boundary layer on the basis of ozone. Here again, though, the noisiness of the UCATS ozone data cloud the picture in the critical TTL altitudes. By lumping all the WAS data together, the differences in*

the quality of the ozone data between aircraft are essentially blurred. Would, for example, we see the same strong difference in methyl iodide at 300 hPa if each aircraft were plotted separately? Indeed, where do the Global Hawk data leave off? Are Global Hawk descent profiles at Guam used at all in Figure 17? Here again then, as in Section 5, questions about the quality of the UCATS ozone data limit the confidence in the authors' conclusions.
   A new section in the supplementary material has been created to address this entitled “Principal WAS chemicals split by aircraft”, which shows three panel plots similar to figure 17 (figures S1–S3) but with the data from just one aircraft plotted on each. The conclusion from these plots was that there was little data from the CAST aircraft compared to CONTRAST and ATTREX, so this dataset would not have much of an effect on the overall averages, and the overlap between the CONTRAST and ATTREX data occurs only between 150 hPa and 180 hPa. The overall trends in the six principal WAS chemicals hold true when plotting only the CONTRAST data and when plotting only the ATTREX data.

References

Newton, R., Vaughan, G., Ricketts, H. M. A., Pan, L. L., Weinheimer, A. J., Chemel, C. (2016). Ozonesonde profiles from the West Pacific Warm Pool: measurements and validation. *Atmospheric Chemistry and Physics*, 16(2), 619–634.

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