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Interactive comment on "Response of Trace Gases to the Disrupted 2015–2016 Quasi-Biennial Oscillation" *by* Olga V. Tweedy et al.

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We thank the reviewer for very helpful comments. We have taken all the points raised into consideration. Our specific responses/changes are below (in *italic*).

Response of Trace Gases to the Disrupted 2015-2016 Quasi-Biennial Oscillation
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Discussion paper

This paper examines the impact of the 2016 QBO disruption on stratospheric temperature, residual (vertical) circulation and distribution of trace gases (esp. ozone) from the equator to mid-latitudes. The paper highlights circulation and transport characteristics being dynamically consistent with the QBO anomaly. These impacts include an anomalous reduction in total ozone out to mid-latitudes (during April and August anyway) which are at near record lows. This has implications for trends in downwelling UV, if similar events were to recur more frequently in the future. The authors also highlight the possible signature of the QBO disruption in tropical cold-point tropopause temperature and UTLS water vapor. This is a very well written paper and does a great job of highlighting those points it considers important, without the distraction of unnecessary details. I would hope the points below can be addressed quickly as I recommend prompt publication.

Main Points: I. Effect of strong polar vortex: What effect will the unusually strong polar vortex, occurring from early-mid winter 2015/2016, have on the Brewer-Dobson circulation and the redistribution of ozone? Presumably, it would create a weaker BDC and reduced downwelling outside the tropics, and so (vertical) transport of ozone at mid-latitudes. I think the conclusions of the paper also need to reflect these other environmental influences, especially as statements of attribution are being made. Here is a suitable reference for the strong vortex (and AO in general) and perhaps other conditions relevant to the 2016 QBO disruption (and redistribution of ozone):

Cheung HHN, Zhou W, Leung MYT, Shun CM, Lee SM, Tong HW. A strong phase reversal of the Arctic Oscillation in midwinter 2015/2016: Role of the stratospheric polar vortex and tropospheric blocking. J Geophys Res Atmos. 2016; 10.1002/2016JD025288

Scaife AA, Comer R, Dunstone N, Fereday D, Folland C, Good E, et al. Predictability of European winter 2015/2016. Atmos Sci Lett. 2017 Feb;18(2):38–

44.doi:10.1002/asl.721

The reviewer makes a good point and we agree that a strong polar vortex occurring from early-mid winter 2015/2016 is likely to contribute (to some extent) to the observed midlatitude anomalies in late spring and through the summer. Recent study by Strahan et al. [JGR, 2016] showed that the impact of Arctic ozone depletion on the midlatitudes in spring after winters with moderate depletion (such as 2016) was about 5 DU (south of 45N). But they also found that the dynamical impact on O3 due to a strong vortex winter roughly opposed the depletion changes, resulting in very little net impact. Our analysis shows that midlatitude anomalies during boreal summer and fall of 2016 are symmetric around equator, which strongly suggests QBO induced nature of observed anomalies. We have added possible mention of the vortex playing a role in ozone anomalies in the third paragraph of section 4 ("Concluding remarks"); however, a full estimation of exact contribution is a separate study of its own.

II. Effect of ENSO and subsequent interpretation of CPT and H_2O (figure 7). The authors should acknowledge the possible influence of the 2015/2016 El Nino and the perhaps recent trends in CP temperature and pressure. One possible reference might include:

Hu D, Tian W, Guan Z, Guo Y, Dhomse S. Longitudinal Asymmetric Trends of Tropical Cold-Point Tropopause Temperature and Their Link to Strengthened Walker Circulation. J Clim. 2016 Nov; 29(21):7755–71. doi:10.1175/JCLI-D-15-0851.1

We agree that it is possible that strong El-Nino event during 2015-2016 winter could impact CP temperature and pressure. However, the role of this ENSO event and its impact of the distribution of chemical constituents in the lower stratosphere remains an open question. As suggested by the reviewer, we have included in the text the acknowledgment of the possible influence of the 2015/2016 El Nino.

III. How much of the 2016 QBO wind (during disruption) is accounted for by the first 2 EOFs (in U)? In this this regard, how meaningful is it to show PC1 and PC2 during these times?

Figure 2 shows the smaller amplitude (closer to the center) of PC1 and PC2 during the disruption. This means the winds are either weaker than the typical QBO or not fitting the EOFs well. Looking at the variance explained by two EOFs, the answer is that it's not fitting the QBO well. Prior to the 2015, the first two EOFs explain 95.5% of the normalized variance of the deseasonalized smoothed time series of zonal winds at seven pressure levels between 70 to 10 hPa combined while during the disruption it falls to only 71%. Thus, the first two EOF patterns don't match the disruption very well, with the lowest percent variance explained by the two EOFs in the entire data record occurring during the disruption. Therefore, there shouldn't be any objection to plotting just PC1 and PC2 during the disruption as it illustrates how odd the disrupted QBO is.

Minor Points:

(line 104) One for the editorial team: superscript asterisk for TEM residual vertical velocity. Also, a reference for the TEM residual vertical velocity should be added (e.g. AHL, 1987) - *changed asterisk and a reference is added*

(figure 2 caption) "spacial"->"spatial" deriv. spatium (latin). - *changed*

(figure 7) The HALOE H20 measurements show a jump around 2001. Where does this come from? Does it affect the (statistical) significance of your results.

The drop in HALOE H_2O around 2001 is a well reported phenomenon (e.g. Randel et al., JGR 2006). The cause of this drop is unclear, but previous studies have related it to changes in SSTs (e.g. Garfinkel et al., JGR, 2013) and ENSO (Brinkop et al. ACP

2016). This does not affect any of our conclusions.

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