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Comment on acp-2022-174

Anonymous Referee #2

Referee comment on "Zonally asymmetric influences of the quasi-biennial oscillation on stratospheric ozone" by Wuke Wang et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-174-RC2, 2022

Zonally Asymmetric Influences of the Quasi-Biennial Oscillation on Stratospheric Ozone

By Wang et al , ACP

Wang et al investigate the influence of the QBO on total column ozone and stratospheric ozone. The authors confirm previous work on the role of the QBO for tropical and subtropical ozone. The main novelty of this paper is that it finds that the QBO at 20hPa has a zonally asymmetric imprint on subpolar ozone that is especially pronounced in DJF. This zonal structure occurs despite the QBO at 20hPa having a relatively weak impact on zonal mean stratospheric conditions. This result is not particularly surprising, but appears to not have been noticed before. A similar effect is also evident in a chemistry-climate model.

There are several major issues with the paper in its current form as described below. After these are addressed this paper should be publishable.

Major comments:

- I found the stippling on the plots that are intended to indicate statistical significance confusing. On most figures, regions with no discernable anomaly are still stippled, while the strongest anomalies are often not stippled at all. The simplest explanation is that there is a bug somewhere, however I apologize if I misunderstood something.

2. The key results of this paper appear to be only significant at the 90% level, if I understand the paper correctly. This is a fairly low bar. Would all significance in polar regions go away if the threshold was raised to 95%? Relatedly, it is surprising that the zonal structure in Figure 3d (in DJF when zonal structure is strongest) is not significant while it is in the annual average in Figure 2. Presumably this is because there is more variability in DJF, but this just begs the question as to how robust this zonal asymmetry truly is. In particular there is no clear explanation as to why this particular phase of the QBO should have the effect on Z* that it appears to have had over these ~40 years, and so I'm skeptical that additional data will necessarily support the authors conclusions. That being said, the model runs help demonstrate robustness.

3. The dynamical explanation in Section 3.4 (lines 244-247) needs further refinement. Specifically, why exactly is a local ridge associated with more ozone, and a local trough with less ozone, in Figure 11? If it was just meridional advection, then the ozone anomalies should be collocated with the nodes of the height pattern, not the extrema.

4.Much of the discussion and many of the figures more or less confirm earlier published work. (I'm specifically referring to the tropical and subtropical impacts of the QBO.) In this reviewer's opinion these figures can be moved to supplemental material, in order to focus more on the novel results.

Minor comments:

- There are two papers the authors appear to have not cited that are relevant to zonal asymmetries in the polar response to the QBO: Silverman et al 2018 and Elsbury et al 2021. While the focus in the current work differs from these paper, these papers should be discussed
- Line 39-40: It is unclear what is the precise mechanism whereby the QBO affects the polar vortex. Garfinkel et al 2012 find evidence for a different mechanism though it is still unclear which mechanism is most important. This is discussed in the Elsbury et al paper
- There are numerous technical edits that need to be made. Please send the paper to an English editor.
- Line 43 compositions -> trace gases.
- Line 53: the details of where the peaks lay depends on the level used to define the QBO
- Line 59 how are global patterns of ozone important for regional health? Please revise.
- Line 189-190 This discussion implies that the upper stratospheric ozone anomaly is dynamically driven and not photochemically driven. Please provide additional evidence/discussion as to whether photochemical processes are indeed not important
- Line 233-234 implies a specific direction of causality between T and vertical wind anomalies. While the statement is clearly true, the direction of causality is not necessarily clear, as both the T and w responses are fundamentally linked to the wind shear via thermal wind balance and mass continuity.

Elsbury, D, Peings, Y, Magnusdottir, G. Variation in the Holton–Tan effect by longitude. Q J R Meteorol Soc. 2021; 1767– 1787. https://doi.org/10.1002/qj.3993

Silverman, Vered, Nili Harnik, Katja Matthes, Sandro W. Lubis, and Sebastian Wahl. "Radiative effects of ozone waves on the Northern Hemisphere polar vortex and its modulation by the QBO." Atmospheric Chemistry and Physics 18, no. 9 (2018): 6637-6659.

Garfinkel, C.I., Shaw, T.A., Hartmann, D.L. and Waugh, D.W., 2012. Does the Holton–Tan mechanism explain how the quasi-biennial oscillation modulates the Arctic polar vortex?. *Journal of the Atmospheric Sciences*, *69*(5), pp.1713-1733.