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Comment on acp-2022-174

Anonymous Referee #1

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-RC1, 2022

Comments on “Zonally asymmetric influences of the Quasi-Biennial Oscillation on stratospheric ozone” by Wang et al.

General comments

This paper reports a global ozone anomaly and associated meteorological field anomalies due to the QBO. Merged satellite data of the ozone and its column amount, ERA5 reanalysis data, and CESM-WACCM model simulation output are used for analysis. The authors analyzed the difference in ozone and meteorological fields between the westerly and easterly phase composites and showed the QBO signals globally. In particular, the signals at high latitudes showed a clear zonal asymmetry. The authors also discuss seasonal differences in the QBO signals and their zonal asymmetry.

I think the results presented in this manuscript are interesting and scientifically valuable. However, I would like to recommend carefully and thoughtfully describing the correspondence of their results to those in preceding studies that were performed during shorter period and reported as a function of latitude. This would help this research be more valuable in the research field. Moreover, there are some misleading descriptions of chemical effects on ozone anomalies in the tropical middle and upper stratosphere. Therefore, I recommend that some revisions be made before acceptance.

Major comments

As I stated in the general comments, I think that more carefully describing the correspondence of this study's results to results from preceding studies reported as a function of latitude (wave amplitude, zonal-mean zonal winds, temperature, etc.) may greatly improve this paper scientifically. The analysis of the zonal asymmetry of QBO signals is new and interesting. However, preceding studies also imply zonal asymmetry through the wave amplitude or wave flux (E-P flux). For example, Holton and Tan (1980) suggested that the wave amplitude in the high-latitude stratosphere may change depending on the QBO phase. This already indicates a change in the zonal asymmetry of the dynamical field and in the strength of the zonal-mean zonal wind. Figure 12 is an interesting figure that demonstrates the longitudinal phase of the QBO signals and less zonal asymmetry of the geopotential height field in the westerly phase of QBO as compared to the easterly phase using climatology (contours) and anomaly (colors) fields, with a slight phase shift from the climatology of wave number one, which is the dominant mode of the wave activity. I would suggest that the authors explain the connection of the 3D anomalies due to the QBO to the zonal-mean anomalies as a function of latitude.

Another point is that the author should state the chemical effect on the ozone anomaly in the middle and upper stratosphere. To clarify the chemical effect in the QBO, I recommend that the authors show a latitude–height cross section of the temperature anomaly, such as in Figs. 5 and 6, and discuss the possibility of a chemical effect. As shown in Fig.6, positive anomalies of w* are evident above the ozone mixing ratio maximum (around 10 hPa), and accordingly, positive ozone anomalies are also evident, as shown in Fig. 5. The authors said that this positive ozone anomaly was caused by transport above the ozone mixing ratio peak. However, I think that the ozone at these altitudes in the tropics is also influenced by chemistry (e.g., Fig.1 of Solomon et al., 1985). If temperature at these altitudes has negative anomalies associated with the positive anomalies of w*, then the chemical effect should lead to a positive ozone anomaly, because a lower temperature leads to more ozone due to the temperature dependence of reaction coefficients in the gas phase chemistry. Then the positive ozone anomaly is consistent with the chemically induced anomaly as well as the dynamically induced (transport) anomaly.

Finally, the color range around the zero value is indicated by white in the most of the figures. This makes the positive and negative anomalies around zero hard to distinguish. It would be better to change the color scale so that the blue shades can indicate negative anomalies and the red shades can indicate positive ones, with the boundary at the zero value.

Minor comments

- Lines 24 and 25: "Fahey et al., 2018" should be "WMO, 2018"
- Lines 145–147: The explanation of positive and negative anomalies around the South Pole is not evident from Figure 2(a) and (b) because the negative and positive anomalies are represented by the same color (white) in the range [-2, 2].
- Lines 175–176: The positive anomaly over the equator from ERA5 is not separated vertically, which is different from C3S.
- Lines 177–178: The positive anomaly in the upper stratosphere from the CESM-WACCM Natural run is located at a little higher altitude and extended higher than the observations.
- Lines 188–192: The transport effect is important in the lower stratosphere, but I think in the middle and upper stratosphere in the tropics, the chemical effect through temperature change is also important (e.g., Fig.1 of Solomon et al., 1985). For example, the positive ozone anomalies above 10 hPa in the tropics may partly or almost totally be caused by negative temperature anomalies that can be caused by the positive w* anomalies. It would be helpful if the authors could show the latitude–height cross section of temperature anomalies.
- Lines 207–208: If you discuss correspondence to TCO, checking the ozone anomaly around 50 hPa as well as 10 hPa would be necessary, because ozone concentration (molecules per volume) is at its maximum around 50 hPa. Although the anomaly at 50 hPa is described at the end of the paragraph, I would recommend mentioning ozone anomalies at these two pressure levels accordingly.
- Lines 209–211: What is the meteorological field behind this ozone anomaly distribution at 10 hPa? Are Figures S5 and S6 helpful to explain it?
- Lines 239–240: I do not agree. In the framework of gas phase chemistry, a low-temperature anomaly leads to a high ozone-concentration anomaly due to the temperature dependence of reaction coefficients. The region where the low-temperature anomaly leads chemically to a low-ozone anomaly is limited in the polar lower stratosphere where heterogeneous reactions on the PSCs work.
- Line 250: I think that over the Antarctic, the ERA5 data show negative anomalies in the western hemisphere as well as the eastern hemisphere. A zonally asymmetric anomaly is evident only around 60ºS.
- Lines 293–294: I do not agree in terms of ozone in the middle and upper stratosphere in the topics but agree in terms of TCO.