Response to Reviewer 2

This is the first review of the manuscript "The Impact of Increasing Stratospheric Radiative Damping on the QBO Period" by Tiehan Zhou, Kevin DallaSanta, Larissa Nazarenko, Gavin A. Schmidt, Paper # acp-2020-925. The approach of the paper is to conduct sensitivity experiments using 1-D mechanistic model to find an impact of radiative dumping in the stratosphere to QBO period. Experimental parameters in this paper are Newtonian cooling (alpha; unit:s-1)/Brunt-Vaisala frequency (N; unit: s-1), and the upper boundary conditions (G). Diagnostics are monthly zonal wind, and the frequency power spectra using the fast Fourier transform. The results are interesting and relevant to Atmospheric Chemistry and Physics because this paper is trying to ascertain the trend of the QBO period in a warming climate, focusing on the radiative damping that would influence that period. But I suggest a major substantial revision since I have serious concerns about generalization and validation of authors' results. (mainly described in the line-by-line comments).

We thank you for your helpful comments and suggestions and will address them point by point as below.

Major comments

1. Statistical significance L047 "the doubling of CO2 shortens the QBO period by 4.7%" What kind of meaning does a value of 4.7 hold for the science? Results of sensitivity experiments using 1D model mostly depend on an assumption of the experimental design, here in Newtonian cooling profiles of Fig. 1. Can you show realistic vertical profiles of Newtonian cooling with standard deviations? And then, you can estimate errors about the shortening of the QBO period, from an assumption of errors of Newtonian cooling.

The reviewer 1 suggested that we should focus on the interpretation of the hypothesized mechanism and its attendant uncertainties without asking too much of its predictive value. Thus, the numbers such as 4.7% are used for qualitative interpretation rather than quantitative prediction. For example, in Section 4, We found that when the Brunt-Väisälä frequency was decreased by 2.5%, the simulated QBO period was slightly lengthened from 30 months to 30.2 months; we also found that when the scale height in the stratosphere was decreased by 2.3%, the simulated QBO period was shortened from 30 months to 29.3 months. Those findings only suggest that the increase of the stratospheric radiative damping contributes more to the shortening of the QBO period than the shrinkage of scale height in the stratosphere while the contribution of the change in the Brunt-Väisälä frequency is almost negligible. By the way, we also added into the manuscript some discussions on the uncertainties in the relative change of cooling coefficient.

2. Scale height Scale height would be changed in a warming climate. How does the change of scale height due to the temperature change in a warming climate affect the QBO period?

An extra sensitivity test has been conducted. Accordingly, a paragraph has been added in the manuscript (refer to lines 409-417 of the revised version with track changes).

3. Ozone The ozone also affects QBO period. It is useful for readers to assess an effect of the ozone on the QBO period using 1D model in a warming climate. Shibata, K., and M. Deushi (2005), Radiative effect of ozone on the quasi-biennial oscillation in the equatorial stratosphere, Geophys. Res. Lett., 32, L24802, doi:10.1029/2005GL023433.

Yes, ozone does affect the QBO period, and we are studying this issue. This paper addresses the impact of the doubling of CO_2 concentration on the QBO period from the viewpoint of increasing stratospheric radiative damping. According to the latest Scientific Assessment of Ozone Depletion completed in 2018, ozone will heal completely before the CO_2 concentration is doubled. Thus, we chose not to deal with ozone in this study.

L10-16. Why the authors do not show that QBOs simulated in this paper are derived only from planetary waves and that gravity waves are not included? Without manifestation about exploring the response to enhancing radiative damping of only planetary waves in the experiments, their conclusion would lead to misleading.

Richter et al. (2020) pointed out that the largest uncertainty in the response of the QBO in a warming climate comes from the representation of parameterized gravity waves in climate models. Section 5 suggested that high-resolution models such as those used by Kawatani et al. (2011, 2019) be used to further our understanding.

L15-16. Most climate models project a strengthening of tropical vertical residual velocity, as you mentioned in the introduction. This could contribute to projecting a lengthening of the QBO period, which is opposite direction to the authors' conclusion.

As discussed in Sections 1 and 5 of the manuscript, our focus is placed on how the physical processes other than wave momentum flux entering the stratosphere and tropical vertical residual velocity could exert an influence on the trend of the QBO period in a warming climate. This report doesn't intend to answer the question: Will the QBO period ultimately become longer or shorter in the warming climate?

L232. "QBO was not essential for QBO theory" You can estimate QBO power with/without SAO. To what extent does the SAO impact the QBO power spectrum?

QBO and SAO power spectra were not estimated separately. They are plotted separately for the sake of visual effects. As per Plumb (1977), the SAO exerts little, if any, influence on the QBO power spectrum in this kind of model configurations.

Minor comments L301-323. Redundant descriptions. You can omit most of them.

The redundancy has been eliminated.

References

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