

Radiative effects of ozone waves on the Northern Hemisphere polar vortex and its modulation by the QBO

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Reviewer #2

We thank the reviewer for reading the manuscript and providing their helpful comments. We address their issues below.

- Comment #1 - Much of this paper is based on differences between the top half and bottom half of figure 4. However, the authors don't appear to have explicitly calculated the statistical significance of the difference between them. The authors need to confirm that the difference between panels 4a and panels 4c, and likewise between panels 4b and 4d, is actually statistically significant.
- Answer #1- To perform this significance test it would be ideal to have many realizations of each simulation (3D or ZM ozone in the radiation code). Since this is not possible with our resources, we do the following:

1. Take all years of the two simulations - a total of 200 years, and mix them together to one data set of 200 winters.
2. Randomly choose four groups of winters according to the number of east/west QBO winters for each run (two groups for 3DO3 and two for the ZMO3 run).
3. Average each group and take the difference between the east and west groups for each simulation.
4. Repeat this 1000 times to get a statistical distribution of 3DO3 minus ZMO3 east minus west QBO anomalies, for each latitude and height grid point.

We now have 1000 differences of random winters for each run. Statistical significance of the 3D(E-W) and ZM(E-W) is calculated by checking if the difference of the E-W (3D-ZM) is bigger/smaller than the 97.5/2.5 percentile of the difference between the two distributions we got.

The result of this calculation is shown in Figure 1 for the zonal mean zonal wind (top) and zonal mean temperature (bot). In the zonal mean zonal winds the negative/positive values in early/late winter indicate that the E-W difference in the 3DO3 run is stronger/weaker than the E-W difference in the ZMO3 run, corresponding to a delay in the HT signal. The

differences are statistically significant. The delayed HT signal in the zonal mean temperature is statistically significant as well.

This information was added in the Appendix section.

- 5 – Comment #2 - I found figure 12 and its accompanying paragraph to be very confusing. What exactly is F_{yy} ? The y-derivative of the y-component of EP flux? Similar what is F_{zz} ? The z-derivative of the z-component of EP flux? Even if I assume this to be the case, I had serious trouble following the text and the accompanying figure despite multiple rereads. Either the authors need to expand their discussion and help the reader a bit, or remove this entirely as it doesn't appear to be crucial for the rest of the paper.
- 10 – Answer #2 - F_{yy}/F_{zz} are indeed the y-derivative / z-derivative of the y-component /z-component of EP flux. Following this comment we decided to remove this figure and replaced it with a new one (Figure 12) showing only the EP flux divergence differences between the 3DO3 and ZMO3 runs for east/west QBO events. The relevant text is updated on page 11 line 10-16.

Minor comments:

- 15 – Technical comments: The abstract was quite long and wordy. It can almost certainly be shortened without removing key content.
- Answer - the abstract has been re-written.
- Comment #1 - P1, line 8 “in the natural configuration” can be removed. While this may have meaning to someone within the NCAR world, it has little meaning to someone on the outside
- Answer #1 - fixed
- 20 – Comment #2 - P2 line 1 chemistry climate models are also used in air pollution studies and for aerosol studies. See the AER-CHEM-MIP project (<https://wiki.met.no/aerocom/aerchemmip/start>)
- Answer #2 - fixed
- Comment #3 - P2 line 4 the majority . . . do not
- Answer #3 - fixed
- 25 – Comment #4 - P2 line 29 this paragraph extends for 31 lines and is hard to digest! I suggest adding two new paragraph breaks: a first on line 4 of page 3, before “Also”, and a second on line 24 of page 3 before “To understand”
- Answer #4 - fixed
- Comment #5 - P3 line 21 nonlinear is misspelled

- Answer #5 - fixed
- Comment #6 - P4 line 24 tendency is misspelled
- Answer #6 - fixed
- Comment #7 - P4 line 26 I do not understand this sentence. Please rewrite
- 5 - Answer #7 - fixed
- Comment #8 - P4 line 28 ozone wave**s**
- Answer #8 - fixed
- Comment #9 - It may be helpful to add an intro sentence to section 3, rather than diving straight into the nitty gritty of the results
- 10 - Answer #9 - added
- Comment #10 - P8 line 22 composites is misspelled
- Answer #10 - fixed
- Comment #11 - P9 line 4 sentence is repeated
- Answer #11 - fixed
- 15 - Comment #12 - P10 line 34 “descends lower down” it is impossible to infer this from figure 13. This clause should either be removed, or reference made to a different figure.
- Answer #12 - fixed
- Comment #13 - P 11 line 2 the second half of this sentence is very unclear and needs to be rewritten
- Answer #13 - fixed
- 20 - Comment #14 - P 11 line 27 I suggest starting a new paragraph with “While”
- Answer #14 - fixed
- Comment #15 - Figure 1 units are not indicated on the colorbar on the left column
- Answer #15 - fixed
- Comment #16 - Figure 5 is missing units
- 25 - Answer #16 - fixed

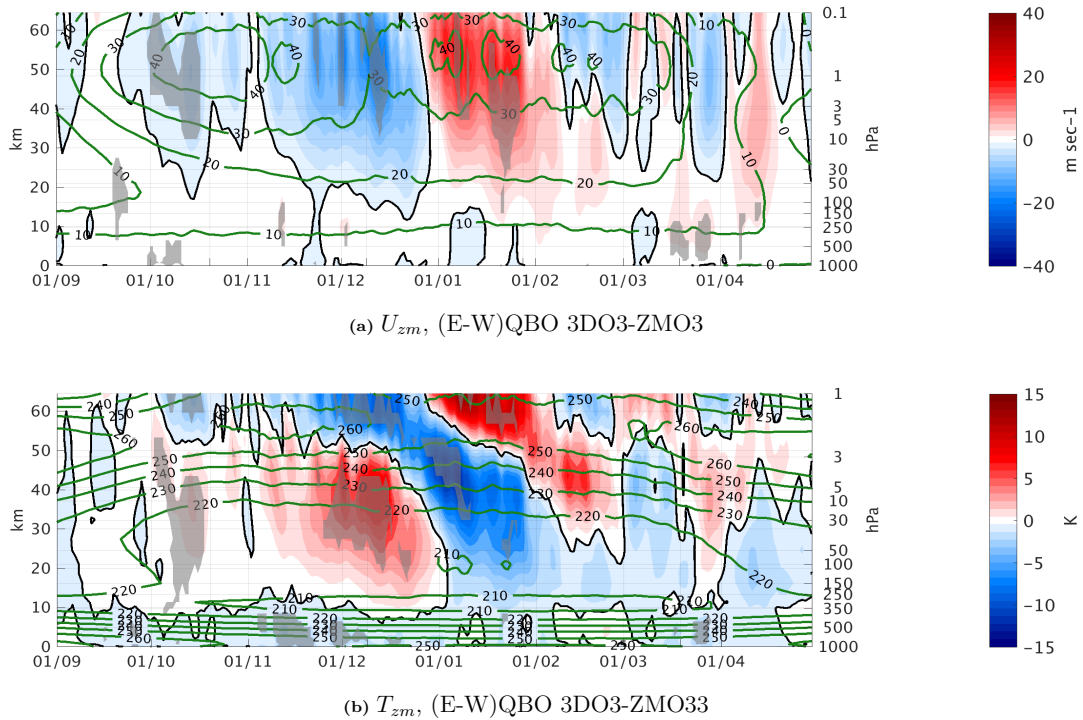


Figure 1. Daily climatology east-west QBO differences between the 3DO3 and ZMO3 model runs of the zonal mean zonal wind averaged over 75-55N (top) and the zonal mean temperature averaged over 90-66N for the 3DO3 (bot), for Sep-Mar. Statistically significant areas are shown by gray shading.

- Comment #17 - Figure 8 is missing the x-label (latitude)
 - Answer #17 - fixed (added to last row of the figure, is it enough?)
 - Comment #18 - Figure 9 either the caption or the figure itself should state explicitly EQBO-WQBO
 - Answer #18 - added to text
- 5
- Comment #19 - Figure 13: The caption should note that a thick line indicates statistical significance (assuming I infer correctly).
 - Answer #19 - fixed

References