

Answer to Reviewer #1 Comments on “Stratospheric water vapour and ozone response to different QBO disruption events in 2016 and 2020” by Mohamadou Diallo et al.

Dear Editor-in-Chief, S. Fadnavis,

We are submitting our revised article titled “Stratospheric water vapour and ozone response to different QBO disruption events in 2016 and 2020”. We thank the three Reviewers for their detailed and well thought-out comments, which helped to significantly improve the paper. We made substantial changes to the manuscript in order to thoroughly address the Reviewers’ suggestions and comments. The main changes concern:

- Merging of the former Fig S3 with the Figure 1 and Figure 2 in the manuscript
- Moving the Fig S4 into the manuscript as suggested by Reviewer #1 & Reviewer #2 and the related discussion.
- Redone all figures to change wind contours, increase font size and to improve their quality.
- Rephrasing of certain paragraphs in order to clarify the manuscript.

With these changes, we are convinced that the paper is highly relevant for a wide-ranging journal like *Atmospheric Chemistry and Physics*. Please see below our answers point by point to all reviewers’ comments and suggestions.

Reviewers comments are in bold, followed by our respective replies. Changes in the manuscript are in blue, allowing them to be tracked easily.

Kind regards,

Mohamadou Diallo (on behalf of the co-authors)

Reviewer #1 (Comment on acp-2022-382):

Diallo et al. investigate the impact of the two QBO disruption events in 2016 and 2020 on water vapour and ozone using ERA-5 reanalyses and satellite observations from MLS. They find differences in the impact these disruption events had on atmospheric circulation and thus on the trace gas distribution of water vapour and ozone. This is a quite interesting study with interesting results. However, the writing could have been generally done a bit better and I have several suggestions for major revision before publication in ACP.

Generally, the whole study and writing is a bit too descriptive and though you state in the abstract that you “quantify” the impact it is done throughout the study in just a “qualitatively” manner. Don’t understand me wrong, I do not need for everything numbers, but if there are too many phrases using terms like “weakly”, “small”, “large” it is quite difficult to get a feeling for how strong actually the impact is. I will provide more detailed feedback on this in the specific comments.

General Comments:

Usage of the term “2016” and “2020” and “2015-2016” and “2019-2020”. In some occasions the whole period is used and in other only the second year of the period is used. I could not really see if there is a concept when you use which term, thus I would suggest to change to one way of writing consistently throughout the manuscript or explain when you use what.

Thanks for the good suggestion. We have rephased and used only one concept of terminology.

In all figures the font size should be increased. In the supplement this should be done for Figures 1-5. We have redone all figures and increased the font size and changed the wind contours.

Use the Copernicus style: Units (km, hPa,.....) are written in upright font.

We have rephased the units.

Your results are based on the measurements from one satellite, namely MLS. I remember that there are significant differences in the QBO imprint on the trace gases between different satellites. How does that affect your results? Have you done a similar analysis using another satellite instrument? What where the differences?

MLS water vapor and ozone products are the best available stratospheric trace gas measurements for the purpose here when considering both measurement uncertainty and sampling issues. Data from ACE-FTS, for example, has a much lower sampling frequency in the tropics, the key region for estimating QBO effects. Most of the satellite merged H₂O and O₃ products available (SWOOSH, BASICS,...) are actually using MLS. So we think using MLS data is the best we can do here.

Some figures of the supplement as e.g Figure S5 should be moved to the manuscript since they are discussed in detail and seem thus to be not that unimportant. There are also some other figures in the supplement that also could be moved to the manuscript.

Thanks for the good suggestion. Figure S5 is similar to the current Figure 6. We have rephrased the paragraphs (Pages 16–17) and moved former Figure S3 and S4 into the main text.

Specific comments:

1. **P1, L6: “weakly decrease”. Be more precise. Decrease by what? What exactly causes the decrease? The BDC transport?**

We have rephrased the abstract (Page 1, line 1-20).

2. **P1, L7: Here you talk about “circulation anomalies”, but before you talked about changes in the trace gas distributions (their abundance). I would prefer a clear separation in the language between dynamical processes and their consecutive imprint on the trace gas distributions.**

We have rephrased the abstract (Page 1, line 1-20).

3. **P1, L17: Here a 1-2 sentence description what the BDC is should be added.**

We have included a sentence defining the BDC and rephrased the paragraph (Page 2, line 23-43).

4. **P2, L21: “Ozone is mainly produced in the middle stratosphere and is a good proxy for tropical upwelling”. This is generally correct, but a too simple and not correctly understandable sentence for non-experts. I would suggest to rephrase this sentence and clearly state when and where is ozone produced, how is it transported and why can it be used as proxy for transport.**

We have rephrased the paragraph and included the suggestions (Page 2, line 23-43).

5. **P2, L27: Introduce the abbreviation “QBO” and add a sentence describing what it is. You actually do that in the next paragraph. This paragraph should be moved higher up.**

We prefer having the definition of the QBO in the paragraph reserved to the QBO and its impact on the trace gases. It makes more sense. The acronym “QBO” is now already explained in the first sentence of the abstract (Page 2, line 44-50).

6. **P2, L29: Explain also shortly what dehydration is.**

The dehydration is a common term meaning “the process of losing/removing water or moisture”. We have included a definition (Page 2, line 40-41).

7. **P2, L32: Shouldn’t it read “e.g. water vapour and ozone”. Doesn’t this hold also for other trace gases?**

Yes indeed the QBO impacts all stratospheric trace gases, including H₂O and O₃. We have rephrased the paragraph (Page 2, line 47-48).

8. **P2, L31-36: As stated in my comment on P2, L27 this entire paragraph should be incorporated in the previous paragraph.**

Thank you for the suggestion. We think it is better to have two separated paragraphs: one for the QBO and the other one for trace gases and their modulations for coherency. We have rephrased the two paragraphs.

9. **P2, L52: ...affect the radiative forcing it the Earth’s climate system...” What does that mean? Are we (the society) affected by these disruptions? What are the changes or consequences we experience based on this disruptions? Or are these just interesting for scientists to better understand atmospheric circulation?**

Water vapour and ozone are radiatively active trace gases, therefore, any change in their abundance in the UTLS will impact the the Earth’s climate system, including surface temperatures. We have rephrased the sentence to be more explicit (Page 3, line 62-65).

10. **P3, L68-69: "...high precision and lower systematic uncertainty..." Add some numbers. How high is the precision? Lower uncertainties than what? The former MLS version?**
We have rephrased the paragraph (Page 3, line 87-97)
11. **P4, L112: Rephrase this sentence that either the references are incorporated in the text or so that these can be added in parentheses. As it is done know it is not correct**
We have rephrased the sentence (Page 2, line 53-56).
12. **P4, L116: Differences in the disruptions. Are here references missing? Are you referring to previous studies or is this done in this study? Please clarify and revise text accordingly.**
We refer here to the differences in structure (strength and depth) shown in figure 1a. We have rephrased the sentence (Page 5, line 140-144).
13. **P5, Figure 1 caption: How has the onset/offset be defined? When exactly did this happen. Can you provide year/month of the respective onsets and offsets?**
We have rephrased the captions of Figure 1, 2 and supplement.
14. **P6, L148: What is the "tape recorder". A short explanation should be added.**
This is a common terminology first used in Mote et al. (1996) meaning "large-scale upward advection of the tropical stratospheric water vapor" as we explained it in the text. We have rephrased and added a reference (Page 7, line 179-181).
15. **P7, Figure 2 description: I really have trouble follow your descriptions/explanations. This is really difficult to see from the figures. Could add some guidance for the eye in the figures, like arrows or boxes or any other shape or sign that marks the respective areas?**
Thank you for the suggestion. We have opted the recommendation of the Reviewer 2 by specifying the altitudes ranges and year periods. This option avoids overloading the figures. We have rephrased the paragraphs (Page 8).
16. **P7, L181: I would suggest to rephrase this sentence. Dehydration refers only to H2O not to both H2O and O3. This sentence can be easily misunderstood.**
We have rephrased the sentence (Page 8, line 217-221).
17. **P7-8: This is all bit too qualitative and difficult to see in the figures. Is there a possibility to quantify the changes?**
We have rephrased and added quantifications in the paragraphs (Page 8).
18. **P8, L197: How do you exactly derive the "zonal mean impact"? What has been done/considered here? The difference of the zonal means?**
The impact of the QBO as well as the wildfire are both estimated using the regression analysis. We have rephrased the section 2 data and methodology (Page 4) and paragraph in page 8, line 190-195.
19. **P8, L198: Which AOD data has been used?**
The AOD used is described in the method section 2.
20. **P8, L198: How do you derive the impact? This becomes not clear.**
Please see the method section 2 and paragraph (Page 10, line 234-242).
21. **P8, L216: "Also note the large variability..." Is this visible in the figures? Or do you mean these have been shown in other studies? If the latter is the case references should be added. If the former is the cause the text should be rephrased.**
We are discussing about the large ozone variability in the extratropics in Fig 3c. We have rephrased the sentence (Page 10, line 256-258).
22. **P9, L226: "large" should be quantified or give more information on the differences than just "large".**
We have rephrased the sentence (Page 12, line 265-266).

23. **P10, Figure 3 caption, 3rd line: The monthly mean mixing ratios you are referring here to; are these for the entire time period 2005-2020?**
The time period used here is 2005-2014 excluding the disrupted years. We have rephrased the sentence in the captions of Fig 3.
24. **P10, Figure 3 caption: The sentence “The impact of the QBO ……….” should be incorporated into the main text rather than in the figure caption.**
The terminology of “QBO disruption-induced changes in…” or “the impact of the QBO disruption on…” are equivalent. We have incorporated it through main text.
25. **P10, Figure 10: The wind lines are difficult to see in detail. Thus, I would suggest to add a figure panel showing only the wind.**
The wind lines are the same shown in the Figure S1, therefore, we would like to avoid repeating the same figure into the main text. We have changed the contour of the zonal wind in all figures.
26. **P11, L231ff: Can you quantify these differences?**
We have quantified these differences in O3 in the previous paragraph (Page 11, lines 250-255).
27. **P11, L254: about 10% weaker? How do you derive this number?**
We have inferred the 10% estimate from the colorbar difference in current Fig. 1d and 2c. In 2016, w^* anomaly reaches up to about 40% below 17 km while in 2020 w^* anomaly barely reaches 25-30%. The difference leads to about 10%. We have rephrased the sentence (Pages 12-15, line 287-308).
28. **P11, L259: Fig S4 and maybe some other figures should be rather moved to the main text. It is quite inconvenient to swap back and forth between the manuscript and the supplement.**
Thank you for the suggestion. We have moved the Fig. S4 to the main text and rephrased the paragraphs (Page 14).
29. **P13, L280: Add a marker/box in the figure to better visualize this?**
We have opted to specify the altitude range as suggested by the Reviewer 2, therefore, avoiding to overload the plots. We have rephrased the sentences accordingly.
30. **P16, L348: “large” and “small”. Please quantify this.**
We have rephrased the paragraph and quantified the differences.
31. **P17, L354: “smaller” and “shallower”. Same here as for P16, L348.**
We have rephrased the sentence (Page 16, line 354-357).
32. **P17, L358 and L360: This is really hard to see from the figures shown.**
Based on the suggestions from Reviewer 2, we have specified in the text the region of wave breaking, leading to BDC differences (Page 16, line 358-360).
33. **Supplement, Figure 3: Although you can only show here a specific altitude range, these figures is much more helpful to see the difference. I would suggest to put this figure into the manuscript rather than in the supplement.**
Thank you for the good suggestion. We have moved the Figure S3 into the main text and dispatched it to Fig 2 and Fig. 3.
34. **Supplement, Figure 5: Since this figure is discussed in detail in the manuscript it also should rather appear there than in the supplement.**
Thank you for the good suggestion. We have moved the Figure S3 and S4 into the main text and rephrased the paragraph related to Fig. S5.

Technical Comments and Corrections:

1. **P1, L1-2:** *I would suggest to move “in the tropical stratosphere” to the first part of the sentence so that it reads: “The Quasi-biennial Oscillation (QBO) is a major mode of climate variability in the tropical stratosphere, with”.*
Thank you for the good suggestion. We have rephrased the sentence.
2. **P1, L4:** *Writing it like this is rather misleading. I would suggest to rewrite the sentence as follows:.....on the Brewer-Dobson circulation and respective distributions of water vapour and ozone, using.....”.*
Thank you for the good suggestion. We have rephrased the sentence.
3. **P1, L14:** *The line “Copyright statement: TEXT” is obsolete and can be deleted.*
We have done it.
4. **P1, L29:** *in the air parcels –ζ of the air parcels*
We have rephrased the sentence.
5. **P3, L70:** *Add “e.g”. There are also other studies that document the quality of the MLS H2O data than the ones by Hegglin et al.*
We have rephrased the sentence.
6. **P3, L71:** *Here a capital “U” is used. Later to the wind with a small “u” is referred. This should be done consequently throughout the manuscript in one or the other way.*
We have rephrased the terminology consistently.
7. **P3, L81:** *Rephrase sentence as follows: “In the figures only the 2013-2020 period is shown to highlight the two QBO disruptions.*
We have rephrased the sentence.
8. **P4, L92:** *Introduce abbreviation “ENSO”.*
The ENSO abbreviation is already introduced in Page 3, line 77
9. **P4, L95:** *Introduce abbreviation “AOD”*
We have introduced the abbreviation “AOD” in Page 4, line 120.
10. **P4, L99:** *In In –ζ In*
We have rephrased the sentences (Page 4, line 126).
11. **P4, L105:** *are → were*
We have rephrased the sentence.
12. **P5, Figure 1 caption:** *“U” or “u”?*
We have rephrased the sentence.
13. **P7, L158:** *3-3 → O3*
We have rephrased the sentence.
14. **P7, L159:** *I am not entirely sure, but I would add “a”, so that it reads “we performed a regression analyses”*
We have added the article “a”.
15. **P7, L163:** *citet instead of citep*
We have rephrased to citep.
16. **P8, L186:** *disruption → disruption*
We have rephrased the sentence.
17. **P9, L221 and L225:** *JAS → July-August-September (or July-to-September)*
We mean JAS → July-August-September. We have rephrased the sentence.

18. **P11, L227: add “phase” or “winds” after “easterly”**
We have added “winds” after “easterly.”
19. **P11, L229: JAS → July-August-September (or July-to-September)**
We have rephrased the sentence.
20. **P12, Figure 4 caption: “Tropical averaged of the deseasonalized mean” should be either changed to “Tropical averaged deseasonalized mean residual velocity” or to “Tropical averages of the deseasonalized mean residual velocity”.**
We have rephrased to “Tropical average of the deseasonalized mean residual velocity”
21. **P13, L284: move “in the following” before “we finally” so that it reads “in the following we finally investigate.....”**
We have rephrased the sentence.
22. **P14, Figure 5 caption: space between “(NetF)” and “(a,b)” and between “(contours)” and “easterly” missing.**
We have rephrased the sentence.
23. **Supplement: Check the figure captions. The units should be in upright font (same holds for the manuscript) and in several occasions the O3 in H2O is in italic instead of an upright font.**
We have rephrased the sentence.
24. **Supplement, Figure 3 caption: Add which line is the blue one and which is the red one.**
We have rephrased the sentence.