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Comment on acp-2022-382

Anonymous Referee #2

Referee comment on "Stratospheric water vapour and ozone response to the quasi-biennial oscillation disruptions in 2016 and 2020" by Mohamadou A. Diallo et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2022-382-RC2>, 2022

Diallo et. al use ERA5 data and Aura Microwave Limb Sounder (MLS) satellite observations to quantify the impact of anomalous QBO events that occurred in 2016/2017 and 2019/2020 on the Brewer-Dobson circulation, water vapour and ozone. They highlight the importance of understanding the reasons for disruptions in the QBO because of its impact on climate research within a changing climate by making use of multiple regression analyses to separate the impact of the QBO on the circulation, ozone and water vapour.

General comment:

The paper is well written and well structured, but needs some more precision in some points to make concepts clearer (indicated below). The text is often very descriptive and it easily becomes tedious to read, but this is necessary in order to build the storyline and possible omissions have been applied where concepts for the first QBO disruption are similar to the second. The supplement only contains figures which are used extensively in the text. An effort should be made to include the really necessary images in the text and only put figures and add explanatory text in the supplement that is not necessary to understand the idea behind the paper. It does not help the reader to have to refer to the supplement to understand the main text.

Specific and technical comments:

Most comments I have are questions about understanding and precision.

I noticed that you mix American (A) and British (B) spelling (center (A) vs centre (B), vapour (B) vs vapor (A)). Could you check for consistency?

Line 1: What do you mean with "major mode of climate variability"? Do you want to speak about the disruption as a change to the QBO as a mode of climate variability? Climate change impacting this mode?

Line 3: It sounds as if there was a fixed 28-month period for previous QBO periods when in fact it varied before. Maybe giving a range indicating in what the disruption consisted is better here.

Line 5: Better write "Both, water vapour and ozone in the lower stratosphere" instead of "Both lower stratospheric trace gases"

Line 7: Do you mean "anomalous circulation response" instead of "circulation anomalous response"?

Line 11: Do you mean "hiding/obscuring/concealing" instead of "hidding"?

Lines 21/22: The two following sentences essentially say the same thing: "Ozone is mainly produced in the middle stratosphere and is a good proxy of the tropical upwelling. In addition, ozone variability in the tropical lower stratosphere is affected by variability in tropical upwelling of the BDC." Please revise.

Lines 24/27: Do you mean "natural climate variability, including the QBO" or "modes of climate variability, such as the QBO"? The term "natural mode of climate variability" is confusing.

Lines 33/37: "oscillation between tropical westerly and easterly zonal wind shears" Do you mean "oscillation of the zonal wind"? The easterly and westerly shear zones descend differently.

Line 34: "QBO phases" You have not defined what you mean with phase, here. Looking at a vertical profile the QBO has easterly and westerly phases at different altitudes, so for the Brewer-Dobson circulation one might argue that there is on average no influence.

Line 38: It was not the "anomalous QBO westerlies" but the "QBO westerlies" that got disrupted (by an anomaly).

Line 44: I would write "climate change" instead of "climate changes"

Line 46: Osprey et al 2016 do not mention CMIP6?!

Lines 54/55: This sentence appears not to be grammatically correct because verb and substantive have similar forms. It is better to reformulate the sentence, e.g: "Here we use satellite observations to quantify the similarities and differences in the strength and depth of perturbed/disrupted QBO effects in 2015-2016 and 2019-2020 on water vapor and ozone in the lower stratosphere. "

Lines 60 to 63: Please reform the sentence to make your statement more lucid. The same issue of verb and substantive confusion might occur especially for the non English native reader. You probably mean something like: "Finally, we discuss the main reasons for the anomalous differences in BDC and UTLS composition between the 2015-2016 and 2019-2020 perturbed QBO effects associated with planetary and gravity wave dissipation, which are likely caused by the anomalous surface conditions associated with the strong El Niño Southern Oscillation (ENSO) in 2015-2016 and the strong Indian Ocean Dipole (IOD) in 2019-2020. "

Lines 63/64: Maybe better: "We also discuss the differences between 2016 and 2020 in terms of the particularly warm stratosphere in the context of Australian wildfire smoke in 2020."

Line 69: "lower systematic uncertainty" lower with respect to what?

Line 70: It is better to explain "multi-instrument mean"? From the text it is not obviously clear what you mean without reading Hegglin et al., 2013, 2021

Line 71: I presume that the ERA5 data used is also 2005-2020?

Line 79: "...impact on these monthly..." should be "...impact on the monthly..." or "...impact on the MLS monthly..."

Line 81: "To highlight the two QBO disruptions, figures only show the 2013–2020 period." Do you mean "To highlight the **impact** of the two QBO disruptions, figures only show the **shorter** 2013–2020 period."?

Is the water vapour and the ozone from ERA5 much different from the MLS data? Because it would actually be really good to see the impact of the QBO on water vapour and ozone from 2005 to 2013 to visually see what "normally" happens, maybe as supplement.

Line 89: In this context (mathematical, technical) I prefer "indices" over "indexes". See for example https://books.google.com/ngrams/graph?content=climate+indexes%2C+climate+indices&year_start=1950&year_end=2019&corpus=26&smoothing=3&case_insensitive=true#

Line 90: Please define "tropical" here. (for example averages over 5°S to 5°N)

Line 93: Please define "AOD"

Line 95: "The solar forcing is neglected because our data set is relatively short." You have a data set comprising 16 years. That means that you have more than one solar cycle. I don't think that this is short, especially not because a linear trend does not take into account the end of solar cycle 23 and solar cycle 24. Have you checked whether it matters? Is it too much work to include the solar forcing?

Line 99: There is an "In" too many at the beginning of the sentence.

Line 99: "unexpected tropical QBO easterlies (negative QBOi) developed in the center" Here "in the center" is not clear, what is the center of the QBO? Is there a center? Over which altitude does the QBO exist? There are many questions that you raise by using "center" here. Maybe it is better to say at 22 km). Furthermore, it seems that the disruption already starts earlier than where you indicate at an altitude of 32 km. As the wind shear seems to shift downwards the disruption of the QBO may have been started earlier. By emphasizing your study on the disruption in the altitude range 15 to 24 km you might oversee something? Or are there two independent disruptions, one aloft and one starting at 22 km? The interesting thing is why at 26 km the westerlies persist.

Line 112: The references should not be in brackets.

Line 114: Here you use "center" again. Better indicate the altitude range or 'center of the image'.

Line 119: You say that the disruption is visible in the water vapour ozone plots. This is difficult to judge if you only show 2013 to 2021. In the water vapour plot it even looks as

if water vapour shows a strange behaviour before the onset of the disruption in 2016 that you indicate. Which would point towards a previous event maybe the onset of easterlies at 32 km at the beginning of the year. Tropical ozone anomalies are closely related to temperature anomalies show the QBO disruption, as you say, and are therefore to be expected.

Line 125: "is the most effective" should be "is most effective"

This sentence is not clear. Do you mean that the disruption impacts tropical upwelling via its impact on tropical upwelling? Do you mean the water vapour anomaly minimum at 17 km and the ozone anomaly minimum at 16 km the end of the disruption that you indicated? What do you mean by "when the signal reaches"? Why do you think that this is due to the disruption impact on tropical upwelling (if this is what you meant to say)?

Line 127: You refer to the wind at 30 hPa but this is not shown in the figure. Please add the pressure altitudes to the figure or indicate altitudes in km (with pressure in brackets) whenever you mention pressure altitude in the text. Also indicate where this event happens. Do you mean at 26 km between the two vertical lines indicated, i.e. the uninterrupted westerlies during the disruption?

Line 129: I would not speak about an upward shift of the westerlies. Westerlies are rather maintained longer and reestablish at the top moving downwards.

Line 133: "substantially increased H₂O mixing ratios and decreased O₃ mixing ratios" do you mean "coincided with an increase of H₂O mixing ratio anomalies and a decrease of O₃ mixing ratios anomalies"?

This is true for water vapour anomalies but for the ozone anomalies there is an earlier onset with a slight increase and it does not reach as high up as the water vapour (25 km).

Line 134/135: "sudden occurrence of the QBO 135 disruption". An interesting question here is if the disruption was not caused by this, and the ozone and water vapour response is just due to the thermodynamic balance.

Line 138: the spelling of structural is wrong here (strutural).

Line 145: "compare" should be "compared" (or compares but then there should be an "and" before "suggests").

Line 147: Figure S3 is mentioned before S2 please switch the order of the figures.

Line 158: Spelling: "33 anomalies" should be "O3 anomalies"

Line 160: "The difference... gives the QBO-induced impact." Is it not only "the linear part of the QBO-induced impact"?

Line. 170: I don't really see this. I presume that you refer to the region between the two vertical lines. There ist seems the other way round? Or for water vapour it is negative when the QBOi increases (from negative to positive).

Line 171: Here I would only mention that the ozone anomaly changes follow closely the disruption in the zonal wind. I would not speak about suddenness.

Line 173: Here it would help to have the months as minor tick marks. I can see the alignment with ozone but for water vapour this is only speculation and is not true further up, i.e it might only be true for one altitude level.

Line 179: 40 hPa please also give the altitude.

Line 179/180: The response is different for the ozone and water vapour anomalies. For ozone the altitude range and the temporal extend true but for water vapour it is rather from mid 2016.

Line 182: "anomalously cold point temperatures" should be "anomalously low cold point temperatures"

Line 183: Why is there enhanced tropical upwelling?

Line 184: "indueced" should be "induced"

Line 186/187: I don't understand:

1st statement: disruption induced O3 anomalies are small between 2016 and 2020

2nd statement: disruption induced O3 differences are large between 2016 and 2020

I am not sure what you want to say here. Could you reformulate this sentence please to make it clearer?

Line 192: What do you mean with "early" in "...we note that the early QBO westerly..."

Line 197: "zonal mean impact" what do you mean with "impact"?

Line 201: Are those responses due to the disruption or due to the QBO in general? I.e. Do the responses just follow the stratospheric wind regime no matter if there is a disruption or not?

Line 204: "below the altitude of 20 km": at about 20 km there is the maximum hydration?! It is rather 18 km? You could add minor tick marks to the plot to see clearly where the sign changes.

Line 204ff: How can you be sure?

Line 209f: "but stronger in winter hemisphere" Do you mean "but more in the winter hemisphere" or "but is stronger in the winter hemisphere"?

Line 212: "consistent" Do you mean "correspond"?

Line 226: "particularly large" please indicate what figures you are referring to.

Line 234: "induced secondary circulation are weaker" should I not see this in figure S4a,b?

Line 260: It is very difficult to follow your argument here, especially because the tropospheric w^* differences look very strange. In your argument you don't mention altitude ranges so which makes it difficult to follow.

Line 264: "(Fig. 4c in the supplement)" does not show cold point temperatures. What do you mean with substantially in "substantially negative"? Maybe better "strongly negative"?

Line 266 Figure 4 which you refer to does not show water or ozone? Neither does Figure S4?! Please correct.

Line 279 "hidding" should be "hiding"

Line 297 "net wave forcing is stronger and broader" do you mean the red region between 20 and 25 km altitude?

Line 298 "wave breaking near the equatorward" do you mean the blue region between 18 and 22 km between latitudes of about -20° and $+17^\circ$?

Line 303ff: "The wave forcing evolution..." what do you mean? Adding the components gives you the total? I guess I misunderstand this sentence?

Line 322: What do you mean with "for the tropical upwelling of the BDC differences"?

Line 341: "few months after the sudden shift from the QBO westerly to QBO easterly wind shear reached the tropical tropopause." For ozone it seems to have happened already earlier!

Line 349ff: How can you be sure of this statement? ("strengthening of the tropical upwelling of the BDC")

Line 362 "warmed the cold point temperature" should be "raised the cold point temperature"

In the Figure captions you repeat the definitions for a, b, c etc very often. It would be good to remove the repetitions.

Figure 1: I would prefer omitting the first (a) and putting the ERA in the description under the second (a).

"50hPa" it would be good to have an approximate altitude at 50 hPa to see where we are in the panels (a) to (c).

The QBOi line looks weird because of the disruptions. Also here it would be good to see how regular it looked before. Please add months as minor tick marks.

Figure 4: The labeling seems wrong in the first sentence. What you call b should be c and vice versa. What you call "impact" I presume comes from the multiple regression analysis?

Figure S1: The altitudes in the text refer to pressure altitudes whereas here are only altitudes in km. Please make consistent. The whole year average for Figures a) and b) depends a lot on the phase of the QBO for that year.

It appears that Figure S3 is mentioned before Figure S2 in the text, please reverse order.

Figure S2: There is a mistake: instead of 2016 (a, c) and 2020 (b, *c*) it should be 2016 (a, c) and 2020 (b, *d*).