Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2020-1104-RC2, 2020

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Differences in the QBO response to stratospheric aerosol modification depending on injection strategy and species" *by* Henning Franke et al.

Anonymous Referee #2

Received and published: 12 December 2020

The paper by Franke et al. examines how the QBO varies in response to the injection of stratospheric aerosols in a variety of different locations (single equatorial grid point, two subtropical gridpoints, and in a zonally symmetric sense over 30S-30N) using two GCMs. They find that the QBO response is qualitatively sensitive to the injection strategy with the two-point method yielding no QBO change and the other two methods yielding a QBO change. They also find that the QBO is quantitatively sensitive to the magnitude of the aerosol injection as well as to the injected aerosol type (be it SO2 or H2SO4). They finally demonstrate that ozone plays a role in why the injected aerosol type matters; interactive ozone chemistry is likely required in any future studies on such geoengineering procedures. Overall, they claim that arguments related to thermal wind

balance are sufficient to explain the changes and sensitivities that are found, although I do have doubts about how strong their causation arguments are using this inherently diagnostic relationship (see comments below).

I found the manuscript to be very interesting and well-written. My comments are mostly based on clarity and improving the presentation and although I have written a number, please take this as me being genuinely interested in the results. Hence, my suggestion is of minor revisions.

Minor and technical comments: Lines 31-32; Can you state explicitly here why this led to a prolonged westerly QBO phase? Did Labitzke (1994) provide reasoning? Presumably because the temperature anomaly leads to stronger upwelling below the westerlies that counteracts the downwelling that is ordinarily associated with the westerlies?

Line 44; 'further' –> 'also'

Line 54; Not sure what this sentence means. Please rephrase. Do you mean qualitatively similar but quantitatively different?

Line 75; delete 'one'

Line 85; which parameterisation? Can you be more specific here?

Line 124; Why is CESM not run using the single-point injection setup?

Table 1; it needs to be stated whether the total aerosol load injected in the, e.g., 25Tg experiments is the same across the different injection locations - i.e., is the 25Tg version of the region experiment spread over the entire zonal band so that the 25Tg point source run is inputting the same amount of aerosol? Otherwise I fear that one is not comparing apples to apples when one writes sentences such as on lines 150-151. A clearer example is whether the 2-point run has two point sources of 12.5Tg to match the 25Tg in the single-point source run. You also need to presumably take into account the grid box size in this calculation as a 25Tg single point run at the equator is not equivalent to a 25Tg run at 15N due to the smaller grid box size further poleward.

Lines 131-133; I think a bit of background as to why these values are prescribed would be useful. Are they typical of the amount of aerosol injected in a volcanic eruption? Or are they generally used in current literature?

Section 3.1; The word 'disruption' in the title seems like a bit of a misnomer as thermal wind balance holds. The injection that causes changes in temperature and wind are in thermal wind balance with one another.

Line 172; why is this experiment chosen to present herein? Is there a linear relationship between the experiments so that the temperature anomaly in the lower stratosphere for the so2-5 run is five times smaller than the presented so2-25 run? Also, change 'exemplary' to 'exemplarily' (also in other places in the manuscript).

Line 174; what does 'usually positive poleward' mean here? Fig 3a shows the temperature gradient anomaly in the experiments where the aerosol is injected. Do you mean the Ty anomalies associated with the QBO in the control run?

Lines 183-184; Does figure 2b really show a more uniform meridional heating profile?

Line 185; still in the lower stratosphere though so I think this is worth reiterating. Aloft, it is not true.

Lines 196-197; I do not see this slight intensification of Ty between 15S and 15N - if anything there is a dipole across the equator. Please clarify. Lines 170-201; I think you need to be careful about the causation argument here. Indeed, thermal wind balance holds even at the equator. But the wording is very much stating that the aerosol injection changes the temperature structure which then leads to wind changes. Thermal wind balance cannot explicitly tell us this. This is even more clear aloft where there are large Ty and Tyy anomalies where the aerosol injection does not reach and it is hence the causation is less clear.

Lines 203-206; This is true when comparing different injection locations, but not true if you compare different magnitudes injections at the same forcing locations (I also asked

before, is there a linearity in the temperature anomaly and wind anomaly in response to different magnitude injections? It appears that there might well be from figure 4 when comparing the 2xblack-line experiments). As I also stated, I am worried that comparing the different forcing locations is misleading if the overall injection magnitude is not the same.

Lines 207-210; I do not follow this. Can you be clearer here?

Lines 223-224; You only state this observation here in the runs, but it is not unexplained. It is not clear to me why the lower stratospheric anomalies lead to such strong w anomalies aloft compared to closer to the injection location. Please explain if it is known why.

Line 230; the static stability changes in the tropical stratosphere though, right? Is there also a change at higher latitudes that affects the planetary wave propagation in the way that Chen and Robinson (1992) espoused? My guess is that it is due to the change in winds at higher latitudes that changes in planetary waves occur.

Lines 237-238; How can you attribute the $w>0$ anomalies in fig 5 to the SMC as opposed to just a change in the BDC?

Line 247; Is there a threshold above which the injection acts to no longer drive an oscillating QBO but instead drives constant westerlies/easterlies? At some injection rate between 5 and 25, there must be a crossover, the knowledge of which would presumably be useful for policy planning.

Figure 6; The 5S-5N meridional average is not a good measure for Tyy given that Tyy looks pretty symmetric about the equator (fig 3) so that the two likely cancel. I suggest to split into 5S and 5N (which should likely be antisymmetric).

Figure 7; at what height is this line plot?

Lines 271-274; Is the difference between these different injection-species runs significant? It looks to be a very minor difference (also between 2nd and 3rd columns of fig

1).

Figure 10; the final sentence of caption is confusing given that one of the experiment lines is also dashed black. I also think that you need to perform experiments with either 10 or 15Tg rates so that you can more confidently draw the lines of best fit as you have here. This harks back again to the linearity point I made before.

Figure 11; It would be useful if you included the periodicity of each QBO run in each individual figure panel so that the reader can immediately read it off without having to find the associated text.

Figure 12; the thick black denoting u=0 is difficult to distinguish from the thin contours. Please thicken.

Lines 308-309; 'in principle' –> 'qualitatively' given that 12c-d have similar spatial u anomalies. However, figures 12a-b essentially show no difference at all so it is being generous to include them in this sentence.

Lines 313-314; In fig. 12c,d I do not agree that the Ty is stronger and more poleward spread in CESM. In fact, the opposite looks true with ECHAM having stronger Ty anomalies extending poleward. Please clarify.

Line 318; I do not follow why the smaller AM-SO4 sulfate particles can explain the difference in Ty given that, presumably, they are the same size in the two models. I may be misunderstanding something but please make clearer.

Line 330; 'on' –> 'with'

Line 338; This is true only for the lower-stratospheric QBO.

Line 357; correspond to the positive anomalies of the sulfate mass mixing ratio? i.e., there is an anticorrelation.

Lines 363-368; Again, this is assuming a chain of causation using the thermal wind balance. Given it's inherent diagnostic nature, it is not possible to assume with such

certainty this causation chain. It is advisable to be more speculative here.

Line 371; partial

Lines 369-382; Another way to check (that is more robust I think as it brings the two models closer to one another) would be to switch off the interactive ozone in CESM and rerun the two experiments corresponding to figures 11j,k. Then you could see if the two models have similar QBO winds (i.e., does the CESM relinquish its constant lower-stratospheric easterly phase?). I am not sure how difficult this is to do however - is there a simple namelist parameter that can turn off ozone in CESM.

Eqs R1-R2; For someone that isn't an atmospheric chemistry wonk such as myself, these equations don't mean too much unless they are properly introduced (a couple of the terms are obvious, but most are not!). Can you explain each of the terms so that everybody can understand?

Lines 419-426; Please see prior comments on thermal wind balance. These are very strongly worded claims using an equation that does not yield itself well to causation arguments.

Line 466; assess

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-1104, 2020.