Response to Editor

Editor Decision: Publish subject to minor revisions (review by editor) (22 Mar 2021) by Peter Haynes

Comments to the Author:

You have made substantial changes in response to the comments of the two referees, so the paper is now closer to being suitable for publication. However, having looked at the revised paper carefully my view is that way in which the changes have been made is potentially confusing. I was considering sending the paper back to the referees for their comments, but have decided against that for the moment.

I have set out below the two aspects of the revision that I see as confusing. Please consider making appropriate changes or else provide responses arguing why no change is needed.

I hope to be able to accept the paper for publication at the next stage of the process, but to do so I need to feel that the referees' comments have been properly addressed, in a way that does not confuse the reader.

Thank you very much for your critical review. As a result, our paper has been thoroughly revised, and becomes clearer and more coherent. Hopefully, we have satisfactorily addressed all of the referees' concerns.

(1) radiative damping

Referee 1 made the point that the Plass (1956) paper which you originally used to motivate and quantify increased damping rates associated with increased CO_2 really says very little about change in damping rate. As the referee recommended -- and I think this is the approach you have taken. But you still make significant reference to Plass (1956) as you present the details of your approach.

The bottom line is that the idea of damping rate and ways to calculate is well-developed in the literature, including the idea that damping rate may change as a result of increased CO_2 -- see Fels (1985) for example. Bringing in Plass (1956) and then explaining why his results are not relevant is a complete distraction. If you want to acknowledge to the contribution of Plass (1956) in, for example, recognising that the radiative properties of the stratosphere will change with increased CO_2 then do that in the introduction -- though his was one of several contributions on effects of increasing CO_2, with the paper of Manabe and Wetherald (1967) being the most frequently cited (appropriate in my view if one takes account various important innovations in their calculation).

I have given 3 examples below where the text needs attention in this respect.

- L128-133: "Given the fact that the QBO period is influenced by the radiative damping (Plumb 1977; Hamilton 1981), a natural question to ask is whether it could play a role on the trend of the QBO in a warming climate. Plass (1956) showed that when the CO2 concentration is increased from 330 ppmv to 660 ppmv, the cooling rate increases significantly in the middle and upper stratosphere while it is not changed below the 24 km height level. The cooling rate is increased by about 50% around the 40 km height level (see his Figure 8)."

  If we agree that Plass's calculation tells us little about damping rate -- then the above sentences are very confusing -- most reader will assume that there is a connection between 'radiative damping' in the first sentence and 'cooling rate' in the second.
- L207-216: "Since the cooling rate is increased by about 50% around the 40 km height level (Plass, 1956), the radiative damping rates are expected to also increase in the middle and upper stratosphere as the CO2 concentration rises. However, the relative change of cooling rate Q in response to the increasing CO2 is not identical to that of Newtonian cooling ..."

Again the Plass has very little useful relation to the proper calculation of damping rate, so what is the point in referring to Plass (1956) and then saying in the following sentence that a different calculation to that in Plass (1956) is needed ...?

- L222-226: "In FIG. 1b the black line depicts the ratio for the broadband longwave radiation (5 μm −100 μm) and the red line delineates the ratio for the CO2 absorption band (12 μm − 18 μm) used by Plass (1956). For the CO2 absorption band, the calculated ratio is evidently comparable to the ratio of cooling rates between the doubled CO2 and the reference CO2 shown in figure 8 of Plass (1956), with an additional small increase (<1.1) below the 24 km level."

  Again, what is shown in your Figure has very little to do with Plass (1956) -- his Figure 6 shows cooling rate -- calculated on the basis of a fixed temperature profile and various CO2 concentrations. An essential part of your calculation is the heating/cooling rate difference arising from a temperature difference. In trying to bring in Plass (1956) here you are actually undermining the credibility of your own (updated) calculation.

We agree with you that Plass (1956) is a red herring. Accordingly, it has been removed.

(2) Effect of ozone

Referee 2 suggested that the effect of changing ozone on the QBO might well be as important as that of changing damping rates due to increasing CO2.

You don't mention the possibility of an ozone effect on the QBO until Section 4. (You mention the effect of the QBO ozone earlier, but that is different.) Then suddenly you give L344-354, which focuses only on the effect of ozone on the thermal damping rate, via its long-wave effect -- and essentially dismisses any role for ozone, when your reply to the referee has seemed to say that ozone is complicated and the resolving the role of ozone is not within the scope of your paper.

In order for the reader not to be confused by this there needs to be some introductory sentence somewhere which introduces the idea that changes in ozone may be important and furthermore it needs to be acknowledged that changing ozone may affect the QBO in other ways -- for example the Hasebe (1994) paper focuses on the short-wave heating role of ozone. As with your paper as a whole, you are in any case considering only one part the QBO mechanism -- the radiative damping of planetary-scale waves -- when there are many other parts of the QBO mechanism that may change as a result of increasing greenhouse gases -- and that includes parts that involve changes in ozone. You acknowledge this point in a fairly general way in the final sentence of your abstract and more clearly in the final sentence of the paper. Your paper will be more, not less, valuable if you make this point as clear as possible.

We have revised this part significantly and have tried our best to make it as clear as possible.