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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The influence of mixing on stratospheric circulation changes in the 21st century" *by* Roland Eichinger et al.

Anonymous Referee #2

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The paper presents an analysis of the trends in the Brewer-Dobson circulation in 10 chemistry-climate models of CCMI-1. The contributions of residual circulation and mixing to the changes in AoA are separated by computing RCTT, A_mix, and mixing efficiency for each model. It is found that in most models the mixing efficiency decreases throughout the 21st century, and this explains about 10 % of the AoA changes. It is shown that different evolutions of mixing efficiency can partly explain the spread in the AoA model trends. Finally, it is argued that the decrease in mixing efficiency can be attributed to changes in the PV gradient, which increases due to stronger stratospheric westerly jets in the future.

The paper is very well suited for ACP and the CCMI special issue, provides novel results which make advances in understanding the future trends in the BDC and the role

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Discussion paper

of mixing in predicting the future evolution of stratospheric circulation. I do not have major comments on the content, but the paper would benefit from some work on the writing to clarify and simplify the message (especially in sections 3.2 and 3.3). I recommend publication after the following suggestions to improve the writing are addressed.

Specific comments:

- P1 L5 and P23 L9: could you provide a rough number to quantify the model spread in AoA trends? (also in the conclusions, on P23 L9)
- P3 L31-32: It is not clear what is the difference with the previous sentence.
- P6 L20-21: I do not understand why a term is needed to correct for the altitude dependence of the vertical residual circulation, when w* is already expressed as a function of z in Eq. (1). Perhaps you could briefly explain this?
- P6 L18: Is alpha a function of z? If so, it should be reflected in Eq. (1).
- P6 L29: Did you use wstar provided by the models or compute it from vstar?
- P6 L30: The tropical profiles provided for the TLP model: profiles of what variables?
- P7 L1: obtained by a best fit: of the TLP parameters to the model's age of air? (specify what is fitted)
- P7 L32 – P8 L2: Remove this sentence, already mentioned before.
- Figure 2: Perhaps it is worth mentioning that the observations have a much larger spread than the models' variability.
- P9 L13-14: (as both. . .) : this cannot be concluded from those papers

- P10 L3-4: This separates. . . : Not really separates, but you can argue that, based on the sensitivity experiments in Polvani et al. 2018 GRL showing that the change in the slope is due to ODS, one can capture the GHG effect alone by considering the net trends from 1970-2100.
- P12 L11: GEOSCCM does not belong to this group in my opinion, it is more similar to SOCOL and WACCM. Also, NIWA and ACCESS are very similar.
- P12 L16: 'slightly positive': remind here that this means values of the ratio above 1.
- Figure 4b: over which latitude band do you average w* at 70 hPa?
- P13 L14: '10 year moving average': this averaging is not mentioned in Section 2.2.
- P14 L3-4: in MRI and EMAC-L90 the trends are near zero in the first period, the only model that shows a clear increase in epsilon in the first period is ULAQ.
- Figures 4 and 6: These correlations are based on ten points (one for each model). It would be interesting to see, perhaps not for the paper, what do the correlations look like for one single model on interannual variability. Do they show similar features?
- P16 L4: it would be clearer for the reader if the intermediate step AOA'(2100)=A_mix(1970)+RCTT(2100) were included.
- P17 L9-13: This description of Table 3 is confusing. The sign of the fractional impact of mixing efficiency on AoA changes is negative for three models. It seems to me that this should be the first thing mentioned and explained clearly. The models in which this contribution is negative are the same only three models for which $\Delta\epsilon$ is positive. So in these models the mixing efficiency is increasing over

time, and that is why they make an opposite contribution to AoA trends. Is this correct?

- P18 L7-8: However, it is not strictly coincidental... I do not understand this sentence.
- P23 L3: AoA decreases

Technical:

- P3 L23: aging by mixing, and residual....
- P6 L10: via → from
- P6 L16: add a reference (Neu and Plumb 1999, Garny et al. 2014)
- P6 L26: that counts → valid
- P6 L27-28: remove 'however' or 'nevertheless'
- P7 L2: remove 'therefore'
- P7 L5: indirectly → inversely
- P7 L20-22: Is this paper published? Otherwise it should not be cited. Also on P12 L4-5.
- P7 L23: remove 'it were'
- P7 L24: remove 'and these models'
- P7 L26: the lower end

- Table 2 caption: typo 1980 → 2080
- P10 L16: Hence → Specifically
- P14 L6: filter out
- P14 L13-14: Rephrase: The mechanisms for the mixing changes are diagnosed using the potential vorticity gradient in Section 3.4.
- P15 L3: remove ‘,’
- P15 L7: remove ‘also’
- P15 L8-9: Rephrase: connected with changes in both mixing and residual circulation.
- P16 L10: remove the second ‘difference’.
- P17 L5: Remove the first sentence (repetitive), start with: The difference between...
- P18 L4: model range → model spread
- P18 L4: (from 0.35 to 0.22) units? (also missing on Fig. 8).
- P18 L9: remove 25%-33%
- P19 L3: ‘...mean (MMM) diagnostics’ (without the final s)
- P19 L24: ‘zonal means’, ‘due to data availability’
- P19 L29: remove Jr.
- P21 L1: (2016) Also correct the reference, the 2017 JAS paper is different from the 2016 JAS paper (both cited here).

- P21 L3: indirectly → inversely
- P22 L1: remove ‘also’
- P22 L9: remove ‘in’
- L10: cannot
- P23 L17: remove (i.a.)
- P24 L4: appear
- P24 L9: the obtained hypothetical. . .
- P24 L24: increases faster and this $\Delta\epsilon$ is negative. . .
- P24 L28: Overall → In summary
- P24 L29: remove ‘a further’
- P24 L30: we further showed

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