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Reply on RC1

Felix Ploeger et al.

Author comment on "The stratospheric Brewer–Dobson circulation inferred from age of air in the ERA5 reanalysis" by Felix Ploeger et al., Atmos. Chem. Phys. Discuss.,
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Reply to Reviewer 1

We thank the Reviewer for the positive evaluation of the manuscript and the good comments. In the following, we address all comments and questions raised (Reviewer's comments in italics). Text changes in the manuscript are highlighted in color (except minor wording changes).

General comments:

{\it I think that the apparent step-change extratropical in age around the early-mid 1990s is an interesting result and one of the clearer differences between ERA5 and ERA-Interim. The fact that this does not appear clearly in observational data (e.g. Fig. 10) may bring into question the reliability of ERA5 trends. It's also interesting that this step-change is not apparent in the tropical upwelling (Diallo et al. 2020, their Fig 12). I might encourage the authors to elaborate a little more on this in the paper as the result is not very prominent. In particular, do any TEM diagnostics of the circulation show this step change, or is this only seen in age calculations? Is so, could the authors speculate as to why? If this step-change is not thought to be real, do the authors have any suggestions for what change in the assimilation scheme may be responsible?}

This is indeed a very good question - and not easy to answer. At first glance, the change in age of air in the mid-nineties appears as a sudden step-change, but a closer look shows that the change occurs over a few years, between about 1991-1995. This change is clearly evident in ERA5 age, and to a weaker degree also seen in ERA-Interim. The age time series in Fig. 9 show that the clearer step change in ERA5 in the mid-nineties is mainly a result of the positive age trend in the eighties and the age increase around 1991 which is likely related to the Pinatubo aerosol. The main difference to ERA-Interim is the trend over the eighties.

As suggested by the Reviewer, we further investigated basic meteorological variables for similar changes, and we considered both the residual circulation vertical velocity and the diabatic heating rate (new Fig. 12 in the revised manuscript). At upper stratospheric levels the heating rates show abrupt changes related to changes in the assimilation system (e.g., in 1998), as discussed for ERA-Interim e.g. by Abalos et al. (2015). However, in the lower stratosphere none of the two variables shows a step-like change in the mid-nineties which could be related to the age of air change. On the other hand, the heating rates

show a decrease after the Pinatubo eruption (1991) in both reanalysis, related to the age increase during the same period. The difference in the strength of this effect between the two reanalysis, and also between heating rates and residual circulation velocity, are not clear to us.

We agree with the Reviewer that a more thorough discussion of these issues clearly improves the paper and we included a new figure (Fig. 12) showing the vertical velocity and heating rate changes and extended the discussion section 6 in this regard.

Minor and Technical comments:

L7: {\it 'Above': it wasn't clear to me what this was referring to as being above. Maybe 'in the mid-upper stratosphere' would be clearer?}

Indeed, our wording here was not precise. We actually meant that ERA5 age appears somewhat high-biased outside the TTL at all locations where we compared to observations. However, we compared only at 20km (aircraft data, Fig. 10a), in NH middle latitudes above 24km (balloon data, Fig. 10b), and in the NH lower stratosphere between about 350-480K (aircraft and balloon data, Fig. 11). Hence, this statement should not be considered as too strong. To be more precise, we changed the wording to:

``At 20\,km and in the NH stratosphere, ERA5 age values are at the upper edge of the uncertainty range from tracer observations, indicating a comparatively slow BDC." Note that we also changed parts of the comparison to observations in Sect. 5, as suggested by Reviewer 2 (we replaced the age-F11 correlation analysis with an analysis of the age difference distributions between model and observations).

L94: {\it theta (potential temperature) should be defined.}

Sentence has been changed accordingly.

L105: {\it along \$\rightarrow\$ along with?}

We just deleted ``along".

Fig. 2: {\it I think this would benefit if a difference plot were also shown (ERA-Int minus ERA5) to aid with comparison of the two reanalyses and with Fig 1 e-g. It is quite difficult to pick out the differences without such a plot.}

Thanks for this suggestion, which eases the comparison! We just added difference plots to all cases (ERA5 and ERA-Interim, DJF and JJA) in Figs. 1 and 2.

Fig. 3: {\it This is a minor point, but I would encourage the authors to consider using a 'perceptually uniform' color scale for the age plots (a,b,d,e), such as grayscale, viridis etc. The rainbow scheme used here can introduce the appearance of false boundaries (where the yellow color are) in the date. The same goes for Figs 4 and 5.}

We agree that the used color scheme could probably be improved. However, most publications we are aware of show age of air using a similar blue--green--red color scheme. As readers therefore are mostly used to that we would stay with it here.

L391: {\it 'strongly overly'. I'm not sure what this means? Perhaps 'decadal variations are significant compared to potential long-term trends'}

We changed the sentence as suggested.

L427: {\it 'steplike change around the year 2000': To me it looks like the main steplike

change in ERA5 is over ~1992-1997 rather than around 2000.}

This is totally correct, and the ``2000" was just wrong - Thanks for pointing this out! We changed the text to ``in the mid-nineties".