

Reply to Reviewer # 1

We thank the reviewer for his/her insightful and constructive comments that definitely help to improve the paper. We have considered every comment carefully. Please find our replies below. The reviewer's comments are given in black, while our responses are in blue.

This paper uses satellite measurements and global model output to identify a recent shift in the latitudinal position of the stratospheric tropical pipe region and the subsequent impact on trend estimates throughout the stratosphere, especially in the extra-tropical regions where a north-south asymmetry has been found in the trends of mean age and a number of trace gases. This is an interesting analysis that highlights another complication in interpreting decadal scale trends and in comparing measurement and model trends.

My main suggestions are to clarify some of the figures and spend a little more time describing the techniques used. Some of the figures make it difficult to see the features described and the paper would benefit from adding a couple of more figures to more clearly show the changes in the subtropical regions. The topic of the paper is appropriate for ACP so I recommend publication with consideration of the modifications suggested below.

Specific comments

Section 2.4: Need to include more description here, likely at least one equation, to help the reader understand the Miyazaki and Iwasaki method.

This will be done. We will include the main equation by Miyazaki and Iwasaki, and provide some explanation. This will go into an appendix of the paper, together with the other explanations of methods requested.

Figure 1: There is no color bar to indicate the mixing ratio values of the colors.

We will improve this figure by providing a color bar and by using another color scale that makes it easier to see the variation of the N₂O vmrs.

Also, why are there gaps in the time series of black crosses, such as in the NH in 2009 and 2012?

Gaps in the time series of black crosses appear where the pdf method to identify the position of the transport barrier was not successful. Due to the specific atmospheric situation the minimum in the N₂O vmr pdf that marks the transport barrier can be such a broad and shallow valley that the determination of the absolute minimum fails or the uncertainty becomes very large. For these cases no latitudinal position of the transport barrier was derived. We will provide this information in the revised manuscript as well.

It would actually be nice to see the PDFs that you used to derive the transport barriers. This could include an average over a particular season for a few years, such as the 2005-8 period and the 2009-12 period. The NH and SH could be shown on the same plot to compare them. As it is, the color scale on Figure 1 makes it difficult to see how well the subtropical barrier represents the tracer gradient region.

We will provide in an appendix of the paper an example of the pdfs used to determine the latitudinal positions of the transport barriers, and explain along this example how the

method works. However, since the positions of the transport barriers have been derived on a monthly basis we will provide an example for a monthly average as well. The pdfs for the full periods would be so blurred due to the seasonal variations of the positions that they would not provide the required information. Further we will refer the paper by Palazzi et al. (2011) that presents examples of pdfs (their Fig. 3). As also requested by reviewer # 2, the color scale of Fig.1 will be changed so that the variation in the N₂O vmrs can be seen more clearly.

Figure 3: Really hard to see everything in this plot. Too many lines and the filled contour colors are too similar to the over-plotted contours.

We will change the color table of the background so that it can be better distinguished from the colored lines.

It would also be nice to see a line plot for each of the two time periods of w^* as a function of latitude, along with the transport barrier metrics, gradient genesis regions, etc. Might need to limit the number of lines you put on each plot though to make it clearer.

We will provide a line plot that contains the requested information for some example altitudes.

In Figures 2 and 3 the southern shift of the southern subtropical barrier is clear after 2009 but it should also be noted that it appears to move back north in 2014. This suggests the shift of the tropical pipe to the south may be a temporary one. I understand this is past the end of the MIPAS record and so doesn't affect the trend analysis. But it's still worth pointing out.

Yes, we'll do that (we do not think that the tropics will move to the South pole on the long term). We will make clear in the paper that it is natural variability on the time scale of (less than) a decade what we observe here.

In Figures 4 and 5, the magnitudes of the changes explained by the shift, especially in the lower stratosphere in CLaMS, are lower than the total changes. This is mentioned in the text as perhaps due to a competing process or processes. Is it possible that your shift of the tropical pipe in latitude is not enough at some levels? Is there a way to test how much shift can best explain the total changes?

In our paper we have applied the shift derived from the CLaMS data on distributions from CLaMS, and the shift derived from the observational data on the respective observational distributions, so the shifts and the tracer fields are treated in a self-consistent manner. In principle, we could find out by trial and error how far the distributions need to be shifted to explain most of the trend pattern. However, we do not see how this could bring us forward.

Figure 6 shows a positive age trend everywhere but in the tropical lower stratosphere.

The negative age trend extends to $\pm 40^\circ$ and up to 800 K (~ 30 km), that is more than the tropical lower stratosphere. Nevertheless, it is true that e.g. the age trend in the region shown by Engel et al. (2009) (mid-latitudinal mid-stratosphere) is indeed still positive. We will note this in the revised version of the paper.

Minor comments

Pg. 7, line 1: change "for" to "of" Pg. 7, line 14: remove "in reality" Pg. 8, lines 2- 3: ". .
.found an increase in HCl volume mixing ratios in the Northern Hemisphere and a decrease
in volume..." Pg. 8, line 4: "...change in age of air..." Pg. 10, line 15: ". . .during the westerly .
."

Thank you for these corrections, we'll apply the changes.