

Interactive comment on “Observed temporal evolution of global mean age of stratospheric air for the 2002 to 2010 period” by G. P. Stiller et al.

Anonymous Referee #1

Received and published: 14 November 2011

This manuscript presents an analysis of the temporal variations in age calculated from MIPAS SF₆ measurements. Some very interesting changes in age (on seasonal and longer times) are presented, and these results have the potential to have a major impact on our understanding of stratospheric transport. However, more evidence is required to show that the age estimates are realistic, and that the temporal variability shown is real and not an artifact of the uncertainties / variability in the measurements. As described below, the ages from MIPAS are much older than other estimates, and some of the spatial variations in seasonal amplitude and linear trends are not "expected" and should be detected in long-lived tracers if real. Also, there are large trends at the tropical tropopause where age should be fixed at zero.

Major revisions are required before this manuscript will be acceptable for publication.

C11843

In particular, the revised manuscript will need to (i) include comparisons of MIPAS age with other observations, (ii) focus on 2005-2010 data period (and hence eliminate the need for a bias correction), (iii) reference the age to MIPAS measurements at the tropical tropopause (so age is zero and time independent there), and (iv) include discussion of independent evidence (e.g., temporal variations of long-lived tracers) that support the presented variations in age.

SPECIFIC COMMENTS

1. There needs to be more evaluation of the MIPAS SF₆ and age calculations. There is limited evaluation or comparison with previous studies of the SF₆ data or age calculations used in this study. Such a comparison is needed to convince the reader that the age calculations presented are reasonable. In particular, you need to explain why the values shown in fig 5 are much older than other estimates throughout the stratosphere. The very old ages in mesosphere can be explained by SF₆ loss, but what explains the age of 3 yrs at 20 km in the tropics?

I suggest that before the time series plots there needs to be some plots like figure 5, showing a combination of SF₆ and age, as well as different years and/or months. These plots will allow the characteristics of these distributions to be compared with other published distributions, and will also illustrate the temporal variations.

I realize that some evaluation has been done in Stiller et al (2008) (and this paper is referenced a lot), but they focused on the 2002-2004 data and as indicated below there are clear differences between the two periods. Furthermore, and perhaps more importantly, the differences shown in Stiller et al (2008) are large. On page 28019 it is quoted that agreement is within 0.5 pptv, but this is not what I see in fig 4 of Stiller et al. (2008) where differences in SF₆ from MIPAS and balloon are larger than 1 ppt, with similar differences between nearby MIPAS profiles. Even if agreement is within 0.5 pptv this corresponds to an error of over 2 years in age! This large difference in age needs to be discussed better, especially as much of the paper focuses on variations in

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MIPAS age of less than 1 yr (seasonally or trend).

2. The data from 2002-2004 and 2005-2010 are combined in the analysis presented, but there are clear differences between the data from the two periods. Not only is there a large bias between the mean values but there are also significant differences in the variability within each period. This can be seen in the time series plots in fig 4 and 6. For example, the data after 2005 in fig 6 shows a clear seasonal variation but this is not the case for the initial years.

I don't think the inclusion of the early period adds anything, and I think the focus should just be on the latter period. This will make the paper cleaner and eliminate one uncertainty from the trend calculations.

3. There are significant trends in the age of air entering the stratosphere, but the age should be zero and constant here (otherwise some of the trends are due to changes in tropospheric transport).

It is stated that SF6 needs to be referenced to abundance at the tropical tropopause (pg 28022), but a surface time series is used. (I disagree that we should "not expect any significant delay of upper tropospheric SF6 compared to surface values" (Pg 28021, line 15). I would expect the UT values to be lower, with a delay of around 6 months at the tropical tropopause.) Also, I don't understand why age is calculated relative to surface measurements without corrections for biases in the MIPAS measurements. The use of reference time series from surface measurements results in unrealistic age at the tropical tropopause:

First, as mentioned above, the age at and just above the tropical tropopause is very old. In fig 5 the age at EQ and 18 km is around 2 yrs old, whereas age should be around zero at tropical tropopause. Now this could be just a matter of a uniform shift in the age, but it is not (as next point explains).

Second, and more importantly, there are significant negative trends in age (1 yr per

C11845

decade) at the tropical tropopause (figures 4 and 8). Not only should the age be zero at the tropical tropopause, it should be constant in time.

What is the cause of the trend in your calculation of age at the tropical tropopause? Does this indicate trends in transport within the tropopause, or is this a possible artifact of the measurements near the tropopause.

Regardless of the cause, if age was referenced to the MIPAS SF6 tropical tropopause measurements then (by definition) the age trend there would zero and the trend at other stratospheric locations would be decreased by 1 yr / decade, i.e., locations that currently have a positive trend of 1 yr/decade would have no trend, and those with negative trend would have its magnitude increased by 1 yr/decade. The spatial structure in fig 8 would be the same but magnitude would be different.

I realize there will be added uncertainties defining the reference time series, due to sensitivity to which altitude is used and extrapolating the MIPAS measurements. But these uncertainties need to be considered, and could be larger than the uncertainties you already quote for age trends.

4. The spatial variations in the seasonal amplitude and linear trends of age are large, and not what would be expected. For example, I would expect the sign of the trend in tropical age to be the same throughout the stratosphere, or at least not to oscillate from -1 yr/dec to +1 yr/dec. As all evidence points to a relatively isolated tropical pipe this would require a rapid speed up of vertical advection in lower stratosphere followed by an even large slow down in region above (and maybe downwelling rather than upwelling). Is there independent evidence for this?

Also, I would expect the seasonal amplitude at midlatitudes to be more similar than shown here, e.g. at 25 -30km the amplitude at 40-50S is around 1 yr whereas at 40-50N it is less than 0.5 yr. Now this could what is happening in the real atmosphere and highlight issues with my expectations. However, if the seasonal cycle amplitude in age is as shown then we should see similar variations in long-lived tracers (e.g. CH4,

C11846

N₂O). (Tropical age trends changing from -1 to +1 yr/dec would also leave a signature in these tracers.) Do data from MIPAS or other satellites provide any evidence for these changes in long-lived tracers?

5. The estimate of the impact of SF₆ depleted air is very crude, and the values assumed used for these calculations are very uncertain. I don't see how you can give such precise estimates of the possible effect, e.g., 0.59 +/- 0.08 yr/decade. Does the uncertainty of 0.08 really account for the crudeness of the calculation?

For example, in these calculations you assume an age of 5 yrs, but your own calculations indicate ages much older than this. At high latitudes you have ages between 6 and 10 years, so why not use 8 yrs in your calculation? I could make similar statements about the other assumed values in these calculations.

MINOR COMMENTS

1. It is hard to see how good the agreement is in the upper panel of Fig 2. It would be much more useful to compare monthly mean values of the different datasets (may be with error bars to indicate variability).

2. I also find figure 7 a little hard to follow. Lat-height plots showing deviation of monthly (or seasonally) mean age from the annual-mean age would be much clearer. Could show this for each month or every other month or every season. A reader could easily see the magnitude of seasonal variations and also when peak occurs from these plots.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 28013, 2011.