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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Stratospheric age of air computed with trajectories based on various 3-D-Var and 4-D-Var data sets" *by* M. P. Scheele et al.

M. P. Scheele et al.

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We thank Referee 1 for his very useful comments.

Reaction to general comments

You mention that:
I: *The discontinuity in the applied forecast series is not discussed.*
II: *The increase in the calculated age might be due to a caveat of the method.*
III: *It is not made clear why a larger age of air would be an improvement.*
On these 3 issues we rely mainly on studies, done by others. In the introduction we added several references to the literature. Some relevant results found in the literature are as follows.
(III) A larger age of air would be an improvement because it would give better agree-

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ment to the age-of-air derived from observations (see our Fig 5, and Andrews et al., 2001). Schoeberl et al. (2003) also found excessive vertical transport in the tropics as well as excessive horizontal transport from the tropics to the mid-latitudes when applying analysis-based transport calculations. This led equally to too young age of air, similar to our work confirmed by a comparison to the observation-based age of air.
(I, II) It is not entirely surprising that extended forecasts give a better performance. Tan et al. (2004) linked the unphysical transport to data assimilation, which already suggests that it might be less of a problem for forecasted data. Indeed Wild (2003) advocates using extended forecasts. Our experiments show unambiguously (Figs.1 and 2) that the effect of changing less frequently from one forecast series to another, thus using longer forecast series, gives a better estimate of the age of air. The advantage of the physical consistency of the forecast data appears to be larger than the disadvantage of the discontinuities in these data. Of course results might always be right for the wrong reason, but we cannot imagine such compensating errors in this case.
Meijer (2004) also found that using extended forecasts gives a better Brewer Dobson circulation. In this study, we confirm these results by doing experiments that can be more easily interpreted, since extra pre-processing, needed to calculate the transport in the CTM, are omitted and thus do not affect the resulting age of air.

We revised the introduction, to clarify the link between the literature and our approach.

Reaction to specific comments

1.The expected differences and problems that are introduced by using different forecast series.

In agreement with the findings of Schoeberl (2003) and Meijer (2004) we expect the age of air to decrease with increasing forecast length. In general we hope to get a more realistic, more according to observation-based values, mean age. We are aware of the possible effect of the discontinuities of the forecast series on the computed age, but as these series give a more realistic age, we conclude that this disadvantage is smaller than the advantage of the larger physical consistency of these series.

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2.Confusing remark on ERA40
This was indeed somewhat confusing. In the revised text we have clarified this point. We also mention that our results are not necessarily valid for the entire ERA40 period.

3. Unclear sentence: A trajectory model ...
In this sentence we mention an advantage of the trajectory model relative to a CTM. As a CTM uses pre-processed winds, this pre-processing will lead to errors in the computed age. These errors are inherent to a CTM, and, therefore, also occur when a passive tracer is used.

4. Least- squares fit
Indeed in the old text the computed exponential extrapolation was not really a fit. In the new text we computed a least-squares fit to data between 3 and 5 years, and used this fit to extrapolate beyond 5 years. As mentioned in the text, the quality of the fit is very high. The contribution to the mean age of the extrapolated part is at most 12 %.

5. Tropopause criteria
We use these criteria to assure that we only count parcels that irreversibly have passed the tropopause. The 10% criterion is similar to that used by Schoeberl (2000), whereas the 1 day criterion is similar to that advocated by Sigmond et al. (2000).

6. Run 1997
To be able to compare our findings with TM4-results, we did the pilot study with data of January and February 1997. Later we decided also to focus on the differences between 4D-Var and 3D-Var data. This forced us to use the year 2000, as only for this year both 3D-Var and 4D-Var data are available from ECMWF. Another reason to use 1997 rather than 2000 is that 2000 is outside the observational time window. The measurements, used in deriving the observation-based age of air, were made between 1992 and 1998.

7: Why is less transport more accurate?
See our reaction to your general comments.

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8. How general are the intermediate results?

With respect to the inter-annual variability: Meijer et al. (2004) found that the inter-annual variability is small. We find a similar result in the 50-day runs, using data from 1997 and 2000. Therefore, we feel that the results also apply to other years.

With respect to the resolution:

In the revised paper we have added an extra high-resolution pilot on 4D-Var data (Exp 6 vs. 7) to counterpart the 3D-Var test (Exp. 3 vs. 4). The sensitivity on resolution in the 4D-Var-based runs is larger than in the 3D-Var-based runs, probably due to the higher resolution of the 4D-Var model.

With respect to the assimilation scheme:

More studies, e.g. Velthoven et al. (1996) found systematical differences between 3D-Var data and 4D-Var data. We tested the influence on F(50), with similar results.

With respect to the forecast length and update frequency:

The results, shown in Fig. 1 and Fig. 2 are in line with the findings of Tan et al.(2004), Wild et al.(2003) and Meijer et al. (2004).

In general we did the 50-day studies to test our approach. The value of a 50 day runs is limited, as the mean age is much larger than 50 days. But the differences between the 50-day experiments were as expected from the literature.

9. Possible side effects of repeated use of one year

The annual jump will erroneously force cross-tropopause transport to some parcels that are close to the tropopause. To analyze this effect, we made a histogram, showing the per day transport through the tropopause from January 1 till December 31 at the first yearly jump. During the day around this jump the cross-tropopause transport is about three times as large as the running average. As the parcels that are involved are close to the tropopause, they would probably have passed the tropopause within short anyhow. Therefore it does not show in Fig. 3. As this discontinuity happens only once per year, the effect on the mean age is very small. With respect to the loss of inter-annual variability: see our reply to remark 8.

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10. Quality of fit
See point 4 above

11. Diagnosis of age in the CTM
Meijer et al. (2004) calculated the age spectrum, starting with a delta function in the tropical band between 10 S and 10 N below 200 hPa. TM4 integrated over 20 years to estimate the age at 20 km. height. Andrews et al. (2001) derived the mean age of a comprehensive set of observations of CO2, CH4 and N2O from 1992 to 1998 throughout the year.

12. Season dependency
In the revised text we discuss the seasonal dependence with the July-run. We moved the text about the season dependency from section 5 to section 4.

13: Tropopause definitions not presented properly
We decided to leave out this part, as the computed age of air appears to be relatively insensitive to the applied definition.

14: Figures not properly discussed
We moved some parts of the text of section 5 to section 4 (e.g. see 12). Now Fig. 1 and 2 are mentioned in section 3. Fig. 3,4 and 5 are discussed in section 4.

15: Why less transport is more realistic:
See reaction to general comments.

16: Goal and conclusions do not match
We moved text from section 5 to section 4 (see 12,14), and changed the title of section 5. We added conclusions directly related to the aims of our study in section 5.

Remarks on the technical comments:
We changed the text as recommended. Some remarks:

4 We define passing the tropopause throughout this paper with criteria.
5: Model versions/Assimilation schemes: Both are true. We would like to emphasize

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the difference in assimilation scheme rather than that in model version, since we believe this is the main reason for the differences. We have therefore changed the text accordingly.
17: The inter-annual variability is not the only source of uncertainty in the calculated age. We removed this sentence. The item is better covered by answer to specific comment 4.

Further we changed the title of section 5 to Conclusions and moved some detail remarks to section 4.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 4489, 2004.