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Atmospheric Chemistry and Physics Discussions



# *Interactive comment on* "Quantifying transport into the lowermost stratosphere using simultaneous in-situ measurements of $SF_6$ and $CO_2$" *by* H. Bönisch et al.

**H. Bönisch et al.**

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We thank you for the helpful and constructive reviews. In general, we followed most of your suggestions. In the following you will find detailed answers to your questions and suggestions.

Recent studies have been carried out by Brioude et al. (2008) based on ozone and CO MOZAIC data and by Sawa et al. (2008) based on CO2 CONTRAIL data; on the extratropical tropopause layer, its vertical structure and seasonal cycles in the lowermost stratosphere. Sawa et al. (2008) have shown also seasonal variations of CO2 near the tropopause. Please include a reference of these works and discuss their relevance for your paper.

The focus of Brioude et al.(2008) is on the mixing layer in upper level troughs. This is different from our paper. We used the SPURT data set, which covers the altitude range up to 13.7 km, in order to study the LMS not only in upper level troughs but also in upper level ridges. Furthermore this study focuses mainly on the free LMS above the ExTL or mixing layer. However, we include a reference of this work on page 21231 line 21 as an example for an ExTL study. Sawa et al. (2008) conclude from CO2 aircraft measurements: ' ... (1) fast meridional transport of high CO2 from the tropical troposphere in the summer, (2) active subsidence of low CO2 from higher altitudes in the spring, and (3) relatively weak vertical mixing near the tropopause.' This describes qualitatively some of the results of this study. We include a reference on p-21232, l-7 and p-21238, l-23.

p21231, line 6: 'It is not only important to understand net fluxes across the tropopause but also net exchange rates ...'. To me, 'net fluxes across' and 'net exchange rates' mean the same. I understand that you are talking about the STE net flux and STT and TST fluxes, but your sentence is a little bit confusing. you should say 'net flux across the tropopause' and 'exchange rates', or reword this sentence to make it clearer.

We followed your suggestion.

p21236, line 6: '... show monotonously increasing or decreasing mixing ratio X in the troposphere'. You should add 'with time'

We followed your suggestion.

p21237, line 11: '... negative values for gamma are sometimes derived'. I would say that negative values are always derived for PV values lower than 4pvu and even 6pvu.

We rephrase p-21237, l-11: 'A close look at Figure 2 reveals that negative values for mean age are derived mainly below 4 pvu but in summer and autumn sometimes even up to the level of 6 pvu.'

Line 17 and 18 you say that those negative values indicate the area and the extent



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where extratropical STE influences the LMS. I would say 'predominantly influences' because this is not because your mean age class is positive that there are no negative data in your distribution. Furthermore I am doubtful that the subtropical jet is responsible for the negative values at a equivalent latitude north of say 50N in the lower part of the LMS (below of what you called the free LMS). The polar jet has a stronger impact in this region. You should also mention in your paper the influence of the polar jet below the free LMS (for instance p21238, line 6 to 10), and not exclusively the subtropical jet.

We followed your suggestion to add 'predominantly' (see also our answer on comment of Reviewer 1).

We also doubt and we do not mention in our paper that the subtropical jet is responsible for negative mean age values in mid- and high latitudes in the ExTL (below the 'free' LMS). However, we should formulate our statement on p-21238, l-6 more precisely: 'Thus, the mean age distribution in the LMS above the ExTL is controlled ...'

The reviewer is right and we agree that the polar jet plays an important role in the ExTL region. Therefore we add the following statement at p-21238, l-10: 'Different to the region above, the formation of the ExTL is dominated by rather localised TST-processes (e.g. Dessler et al. 1995; Hoor et al. 2002) whereby irreversible cross-tropopause transport near the polar jet also plays an important role (Fischer et al., 2000).'

p21242 line 6 and 23: How sensitive are the results due to the thresholds that you are using here? I suggest to have a plot with the meridional variability of SF6 and CO2 at the surface.

Sensitivity of the results on threshold 10°S to 10°N for control surface of chi2: The impact on the results is negligible as long as there is no strong meridional asymmetry (averaged over a one year period). That means the results are more or less the same for the averaged 10°S to 10°N, 20°S to 20°N time series from GLOBALVIEW and NOAA/ESRL and for the averaged Mauna Loa - Samoa time series. All these time



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series were typically used for mean age of air calculations.

Sensitivity of the results on threshold 0°S to 20°N for control surface of chi1: The impact of the chosen threshold on mean transit time Gamma1 is relatively small due to the fact that the temporal characteristic of CO2 seasonal cycle is dominated by the NH influence. The phase of the CO2 time series differ not much from time series using other thresholds like 10°N to 40°N or 10°S to 20°N instead. However, it is clear that the results for Alpha1 are slightly influenced by the choice of the threshold, because the amplitude of the CO2 seasonal cycle increases towards the North Pole. In general, the choice of the threshold 0°S to 20°N for control surface of chi1 is motivated by the work of Berthet et al. (2007). Therefore we add at p-21242, l-23: 'Our choice of this threshold is motivated by the work of Berthet et al. (2007). They demonstrated that nearly all 30-day backward trajectories started in the LMS above the ExTL (at the 365 K level) are leaving the boundary layer ($z < 1$ km) between 0°N and 20°N.'

We do not believe that a plot showing the meridional variability of SF6 and CO2 at the earth surface would help here. Especially the meridional variation of CO2 must be displayed for each season. This might be more confusing than it clarifies the situation. Furthermore, it is not straight forward to argue which effect would have the assumption of different control surfaces or different CO2 and SF6 time series respectively.

p21242 line 16 to 18: 'There the TST ... for the LMS'. This sentence is misleading. You should reword your sentence and clearly say that you are excluding here the region of the LMS where the TST through the extratropical tropopause influence the composition.

We rephrase p-21242, l-16ff: 'Due to the strong meridional gradient of SF6 and CO2 in the troposphere, we restrict the mass balance in the LMS to the region above the ExTL, where TST across the extratropical tropopause can be excluded as far as possible (Hoor et al., 2004).'

figure 7: The missing data between figures 6 and 7 are probably the theta/equivalent



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latitude intervals where the assumption that the TST across the extratropical tropopause can be excluded is not valid. Please specify it in the text. Otherwise, explain why there are missing data between figure 6 and 7.

We explained the missing data between Figure 6 and 7 on p-21242, l-7ff: 'Just as Alpha1, the mean transit time Gamma1 can only be calculated in the domain 0.3 years $<$ GammaSF6 $<$ 3 years where our mass balance is defined, but unlike Alpha1, we do not make any assumption for Gamma1 below the area of validity.'

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 21229, 2008.