Response to anonymous Referee #1

We thank the reviewer for her/his valuable comments.

Major point:

• The authors postulate that after the year 2000 not only the downwelling from the stratosphere into the lowermost stratosphere increased (higher ozone in Fig 2 below 100 hPa) but, in addition, the 2-way isentropic transport from the tropics into the lowermost stratosphere has intensified. Fig 4 discusses these isentropic pathways of transport, but some information are still missed. Where does this isentropic transport occur? - below or above the subtropical jet ? The plotted isentropes (dotted line) do not have any numbers of their potential temperature values. So it is important to know if these isentropes are in the range 310-330 K (exchange mainly below the subtropical jet) or in the range 370-410 K (exchange mainly above the jet). Here also some more explanation about the pathway: "inmixing of tropospheric air" (above or below the jet) would be desirable. This is important, because Fig. 4 provides the key explanation of the processes which changed after the year 2000.

Fig 4 shows solely data above the local tropopause, because there is no N_2O/O_3 gradient in the troposphere. That means that the lowest isentrope connecting both correlation curves (tropics and extratropics) is the 380 K isentrope representing the tropical tropopause. Therefore, the isentropes marked in this sketch represent roughly the range of 390 to 450 K (during the summer season) and therefore they are all located in the lower stratosphere. This fact was added to the figure caption and clarified in the text:

p.28409, l.24ff: "The slopes in the tropics and extratropics reflect an upper and a lower envelope and quasi-horizontal transport in the lower stratosphere between these regions, as indicated …"

p.28409, l.27ff: "Thus the slope of the observed N_2O-O_3 correlation in the LMS is a consequence of the relative strength of vertical transport versus quasi-horizontal transport above 380 K."

The explanation, what in-mixing of tropospheric air in Figure 4 really means, is given on p.28410, l.5-11. In general, we use the correlation diagnostic for in-situ data derived below 380 K, but the observed change of the correlation slope in the LMS is driven by transport processes above 380 K. In principle, the N_2O-O_3 correlation is insensitive to the strength of direct transport across the local tropopause from the troposphere into the stratosphere (TST).

However, there is a systematic fault here, because the upper black point of the in-mixing example must be below the lowest isentrope connecting both reservoirs. There is no quasi-horizontal transport of tropospheric air above of 380 K. This will be corrected in Figure 4. Furthermore, we will change the legend of the thin and thick black arrows in Fig. 4:

Thin black arrows: "Effect by in-mixing of tropical stratospheric air (above 380 K)"

Thick black arrow: "Effect by in-mixing of tropospheric air (below 380 K)"

Minor points:

• Introduction, L 10-15

Maybe the authors should also state that the residual circulation, i.e. the transport of mass is driven by the velocity fields (or its representation in the model) and the tracer transport, i.e. the BDC is additionally driven by mixing that strongly depends on the horizontal and vertical gradients of such tracers.

We add for clarification:

p.28400, l.15ff: "This highlights that changes in the upwelling across the tropical tropopause do not necessarily serve as an indicator for changes in the entire Brewer-Dobson circulation, even when approximated by the residual mass circulation."

• Section 3.3, L 14

Discussion of the climatological slope equilibrium is not necessary at this place. Maybe you should remove this sentence.

We skip the part about the climatological slope equilibrium, but we keep the explanation about the gradient equilibrium because it helps to understand the nature of such a linear relationship in the stratosphere.

• Section 3.3, L. 15

Stratospheric character of air is defined by high O3 and low N2O. This is easier to understand than "flatter gradients". Maybe you want to reformulate this paragraph.

The diagnostic used here is the slope or the gradient of the correlation. High O_3 and low N_2O values can be found on the tropical as well as on the extratropical correlation and therefore the description of high O_3 and low N_2O values is not sufficient to characterise stratospheric air parcels. For this reason, we will stick to the termini "flatter and steeper gradients". In this sense, our formulation is not appropriate and we will rephrase it:

p.28410, l.21-25: "The most stratospheric characteristic with the correlation closest to the extratropical lower envelope has been observed in April ... and the most tropospheric characteristic with the correlation closest to the tropical upper envelope has been found in October ..."

• Section 5, L. 25

"stratospheric circulation" - please replace it by BDC, i.e. please follow your original definitions..

The reviewer is absolutely right, we replaced it.

• Section 5, L. 8

"enhanced isentropic mixing" - following the author's definition of the BDC, it is not clear, if the postulated isentropic transport after the year 2000 is due to enhanced advective isentropic transport from the tropics into the lowermost stratosphere (i.e. advective isentropic transport without mixing) or due to enhanced 2-way transport of the tracers (mixing). Here some clarification would be desirable.

It is true that we cannot differentiate unambiguously between the two effects - net mass transport and mixing. This question has been discussed on p.28415, l.2-15. We conclude in this paragraph that it is very likely that intensified residual transport is accompanied by intensified mixing because both processes are driven by wave breaking. Therefore, the statement on p.28414, l.8-9 is a kind of a summary of the following discussions. For clarification, we slightly modify the sentences on p.28414, l.5-9:

"According to our results the enhanced tropical upwelling is associated with an intensification of the shallow residual circulation branch alone accompanied by enhanced isentropic mixing in the same region. Both effects together form an intensified shallow branch of the BDC during the phase of the anomalies. This hypothesis will be discussed in the following. "