

Interactive comment on “Tracer measurements in the tropical tropopause layer during the AMMA/SCOUT-O3 aircraft campaign” by C. D. Homan et al.

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The authors thank the reviewer for his very useful comments and suggestions for improving this manuscript. Replies to the specific comments can be found below.

Referee comment:

In the introduction, the authors cite Ricaud et al. (2007) who “suggest that the maximum penetration of convective systems into the lower stratosphere would occur primarily over Africa at all season”. Nevertheless, the analysis of Ricaud et al. (2007) is based upon MAM data and is therefore not valid for all seasons. Furthermore, this suggestion from Ricaud et al. (2007) is not in agreement with many studies based on

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trajectory calculations such as Fueglistaler et al. (2004) or more recently Berthet et al. (2007). The results from Berthet et al. (2007) show that at all season and especially in JJA, Africa is not an important contributor to TST compared in particular to South and South-East Asia. Based on spaceborne observations from trace gases, other studies such as Park et al. (2007) or Barret et al. (2008) also point to a major importance of Asia concerning TST during NH summer. From assimilated spaceborne observations, Barret et al. (2008) especially show that in August, CO is uplifted up to about 100 hPa over Asia and only up to about 180 hPa over West Africa highlighting the more important role played by Asia concerning TST. Some mention to these points should be made in the introduction. Indeed, according to the present study based upon AMMA airborne observations of tracers in the TTL, during NH summer over Africa, vertical convective uplift reaches 350–360 K and unusually 370 K and there is no evidence of convective overshooting. Homan et al. are therefore in good agreement with Berthet et al. (2007) and Barret et al. (2008).

Author’s response:

We agree with the referee and changed this paragraph to:

“Ricaud et al. (2007) present satellite data of N₂O, CH₄ and CO and radar data in the tropical tropopause region during NH spring and suggest that rapid uplift over land convective regions, in particular over Africa, may be the dominant process of troposphere-to-stratosphere exchange. However, this view is in contrast to a number of other studies showing that the African region is not an important contributor to troposphere-to-stratosphere transport compared in particular to Southeast Asia and the Western Pacific (Fueglistaler et al., 2004; Berthet et al., 2007; Barret et al., 2008; Park et al. 2007b).”

Referee comment:

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Analysing the airborne O₃ profiles over Africa during AMMA, the authors state that “no boundary layer values are observed at the main level of convective outflow at 355 K” and that “above 370 K, the O₃ mixing ratios are up to twice as high as during the SCOUT-O₃ campaign”. According to literature, they explain this difference (particularly above 370 K) by the seasonal variations of the Brewer-Dobson circulation, the AMMA observations being done in July-August and the SCOUT-O₃ observations in November-December. Nevertheless, the important differences observed between the level of main convective outflow around 350 K and 370 K seem more difficult to explain with this dynamical reason. O₃ in the tropical UT is strongly impacted by LiNO_x emissions in the convective regions. There is a large difference in the LiNO_x emissions from Africa and from the Northern Australian, Indonesian region and therefore on the LiNO_x induced O₃ production. All year round (and also in JJA), the tropospheric O₃ columns are much higher over the Atlantic and Africa (zonal Wave-1) than over the Western Pacific (Thompson et al., 2000). Martin et al. (2002) and Sauvage et al. (2007) attribute this O₃ pattern to O₃ production (mostly from LiNO_x) in the UT combined with the subsidence of air masses within the Walker circulation over the tropical Atlantic. In particular, from model simulations Sauvage et al. (2007) infer that LiNO_x are responsible for an annual O₃ enhancement in the UT of 25-30 ppbv over tropical Africa and only 10-15 over Indonesia/Northern Australia. This makes a 15 ppbv difference. The production of O₃ by LiNO_x should be mentioned as explanation for the O₃ difference at the bottom of the TTL between Africa/AMMA and Australia/SCOUT-O₃.

Author’s response:

We meant to invoke the Brewer Dobson circulation here to explain the difference of ozone concentrations only above the TTL, i.e. at potential temperatures above 375 K. In the TTL (here defined as ~350 K to the cold point at ~375 K) the differences are explained by the absence of flushing of the TTL by recent convection and chemical O₃-production over time (including that promoted by LiNO_x). To clarify this section and

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explicitly mention the possible influence of LiNO_x the paragraph has been changed and extended to:

“For most of the flights no boundary layer values are observed at the main level of convective outflow (355 K), thereby suggesting that there is no major flushing of the TTL by recent convection of O₃ poor boundary layer air. The absence of this flushing results in increased O₃ mixing ratios due to production by LiNO_x (e.g. Thompson et al., 2000; Sauvage et al., 2007; Barret et al., 2010) and other ozone precursors. Law et al. (to be submitted to ACPD) indicate that a large part of the air in the TTL originated from Asia about a week earlier, where uplift of ozone precursors could have taken place. An exception appears to be the flight on 4 August when values as low as 30 ppb observed at a level of 355 K indicate more recent convective flushing.”

While we agree with the referee that LiNO_x will have significantly contributed to the O₃-production, we believe that the difference between the Darwin and West African O₃ profiles cannot be easily explained by regionally varying LiNO_x, as the majority of the air sampled in this case is not of regional (i.e. African) convective origin, but originated over Asia (Law et al., to be submitted to ACPD). Rather we believe the difference is mostly due to continuous rapid convective flushing present over Darwin, but much less so over West Africa during AMMA (which is basically in accord with the Walker circulation pattern).

Referee comment:

The authors mention measurements of a number of tracers (CFC’s, SF₆, CH₄) that are not used in the scientific analysis. What is the reason? Are the measurements too noisy? Is the information from those gases redundant?

Author’s comment:

The other tracers measured by HAGAR are not used in this analysis as they provide no additional information about the transport processes described in this analysis.

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The CFCs, CH₄ and SF₆ show basically similar structures as N₂O (albeit with differing vertical and horizontal gradients) and could also be used to examine horizontal transport processes, but they would simply confirm the N₂O measurements. We chose to use N₂O because it is the species measured with the highest precision.

Referee comment:

Fig 1 and 2: a single figure with two vertical axes (potential temperature as main axis and altitude as left axis) would be better than two figures with two different vertical axes.

Author's comment:

The corresponding altitudes of the different potential temperature levels vary too much between flights and even within individual flights to be coupled one to one. Therefore we have chosen to maintain two separate figures such that e.g. convective outflow levels can be discerned accurately in both altitude and potential temperature coordinates.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 25049, 2009.