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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Role of vertical and horizontal mixing in the tape recorder signal near the tropical tropopause" *by* A. A. Glanville and T. Birner

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Reviewer 1 raises an issue, which according to her/him is so critical that it essentially invalidates all major findings in our manuscript. This issue corresponds to our neglecting of the source/sink term in the water vapor budget (e.g. Eq. 1). Specifically, the reviewer argues that explicit dehydration at the cold point tropopause plays an important role for MLS' water vapor at ∼80 hPa, due to the relatively broad retrieval over a ∼3 km layer (which at this level extends from ∼100-65 hPa, i.e. near its lower boundary includes the cold point tropopause).

We'd like to urge the reviewer to consider the following points and perhaps re-evaluate our manuscript accordingly:

First of all, we agree that there is likely a contribution from explicit dehydration to the water budget at 80 hPa, which we neglect. That this wasn't discussed in the submitted manuscript is an oversight on our part. Note that due to the seasonal cycle of the cold point pressure (closer to 90 hPa during boreal winter, closer to 100 hPa during boreal summer), this effect would be expected to be more significant during boreal winter.

However, it is quite unlikely that the neglect of explicit dehydration invalidates our major findings:

1) Our results are consistent between MLS and HALOE (as stated on line 6, page 12), the latter having a better vertical resolution (∼1.5 km) and hence presumably less impact from sources/sinks at the tropopause.

2) Dehydration would produce an additional negative tendency in our budget, especially during boreal winter when the cold point is located higher. However, this would in turn demand a larger positive tendency from the other terms to compensate. This would therefore if anything result in an even larger contribution due to mixing than we diagnose (cf. Fig. 7, possibly a combination of vertical and horizontal mixing) âĂŤ the opposite of what the reviewer claims.

3) Furthermore, we find that vertical mixing is most important during boreal summer when the contribution from vertical advection is too small to keep the tape recorder going (cf. first paragraph of discussion section). But during boreal summer the cold point is lower making the expected contribution from explicit dehydration smaller and therefore contradicting the reviewer's claim.

4) Note also that the lower panel in Fig. 6 shows that a) our synthetic solution does a much better job than Mote et al. at capturing the observed evolution, b) we tend to overestimate the observed values during boreal winter (consistent with the neglect of explicit dehydration), c) we tend to underestimate the observed values during boreal summer (so dehydration would if anything make the situation worse in that season). One possible reason for our bias during boreal summer is that we neglect the potential

contribution of convective hydration (due to overshooting convection, e.g. Corti et al. 2008). Estimates of this contribution for the tropics-mean are difficult and so it's hard to say something more definitive about it. Dessler et al. (2016) recently found indirect evidence that this contribution might be significant for future stratospheric water vapor trends.

5) We'd also like to stress again (as in the paper, e.g. lines 13-21 on page 12) that we obtain physically reasonable differences between pressure and isentropic coordinates. Specifically, vertical mixing does not play an important role in isentropic coordinates and our results for these coordinates are consistent with previous findings in the literature (e.g. Ploeger et al. 2012). However, the contribution from dehydration (or any other sources/sinks) should be largely independent of the coordinate system used, hence it would show up very similarly in both coordinates. The fact that we find vertical mixing to be much more important in pressure coordinates, but not so much in isentropic coordinates, then speaks against it being artificially enhanced due to the neglect of sources or sinks.

6) It's possible that the simple 1-d formulation of our model (as in Mote et al. 1998) misrepresents horizontal mixing and that part of our diagnosed vertical mixing in fact represents masked horizontal mixing (cf. line 19-21 on page 12). Hopefully future work can shed more light on this caveat.

The reviewer also indicates potential issues related to our isentropic coordinate results, but unfortunately doesn't provide any actual argument regarding those results. We appreciate the comment that our presentation is hard to follow / complicated at places and would welcome any specific remarks and suggestions so that we can try to improve the paper at those places.

A couple of other remarks:

- Yes, ERA-i doesn't assimilated water in the stratosphere. However, given how strong of a function of the cold point temperature it is, and given that temperatures are assimi-

lated, ERA-i's stratospheric water vapor should not be considered to be unconstrained. In fact, our Fig. 2 shows that apart from the tape recorder seasonality (i.e. transport strength), ERA-i and MLS agree quite well in the stratosphere (in terms of overall absolute values).

- Please note that nowhere in the paper do we claim that we've found the final answers to the transport problem near the tropical tropopause, nor do we claim that we have 100% proof that vertical mixing is as strong as indicated by our results (e.g. statement on line 7, page 12). Rather, we present evidence that points to a potentially greater importance of vertical mixing for transport just above the tropical tropopause than previously assumed.

Should the editor allow us to submit a revised manuscript, we will include a discussion of sources/sinks along the lines of the above in the paper.

Reference used:

Corti, T., et al. (2008), Unprecedented evidence for deep convection hydrating the tropical stratosphere, Geophys. Res. Lett., 35, L10810, doi:10.1029/2008GL033641.

Dessler, A. E., H. Ye, T. Wang, M. R. Schoeberl, L. D. Oman, A. R. Douglass, A. H. Butler, K. H. Rosenlof, S. M. Davis, and R. W. Portmann (2016), Transport of ice into the stratosphere and the humidification of the stratosphere over the 21st century, Geophys. Res. Lett., 43, 2323–2329, doi:10.1002/ 2016GL067991.

Ploeger, F., P. Konopka, R. Müller, S. Fueglistaler, T. Schmidt, J. C. Manners, J.-U. Grooß, G. Günther, P. M. Forster, and M. Riese (2012), Horizontal transport affecting trace gas seasonality in the Tropical Tropopause Layer (TTL), J. Geophys. Res., 117, D09303, doi:10.1029/2011JD017267.

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