Answer to the referee # 1

April 27, 2018

Dear referee,
we thank you for the thoughtful comments on our manuscript. In the following we reply to them point-by-point. The indicated pages of the answers relate to the discussion paper.

(1) My most serious concern is that this study fails to provide any discussion and comparison to the obviously relevant study by Wrotny et al. (Total hydrogen budget of the equatorial upper stratosphere; JGR 2010). Some appropriate discussion should therefore be added. While it seems clear that this manuscript will disagree with some of the high yield values found in the Wrotny study, the upper stratosphere/lower mesosphere does appear to be the one region where this study shows a yield greater than 2 (Figure 10).

We thank the referee for pointing us to this study, which certainly adds some valuable aspects to our discussion. Some fitting aspects are added to the introduction and the discussion of the revised manuscript.

Text added to the manuscript:

page 2 By analysing satellite based measurements Wrotny et al. (2010) derived a production of H_2O over loss of CH_4 ratio of 2.0–3.7 in the upper stratosphere between 1.0–4.6 hPa, which is clearly ≥ 2.

page 19 This sum ($H + 2*H_2 + 2*H_2O + 4*CH_4$) of 15 μmol mol^{-1} is in accordance with the estimate derived with the CHEM2D model by Wrotny et al. (2010) for the sum of $H_2 + H_2O + 2*CH_4$ being ~ 7.5 μmol mol^{-1} (i.e. one half of $\simeq 15$ μmol mol^{-1}). The individual abundances of H_2, H_2O and CH_4 also agree well with each other.

page 21 This is furthermore consistent with the findings of Wrotny et al. (2010), who calculated a yield larger than 2 in this area as well.

page 23 The study of Wrotny et al. (2010), based on a correlation analysis of satellite measurements, derived a yield of 2.6–2.7 at 1.0 hPa (depending on the satellite product and error assumptions). These are larger than our estimate, which is less than 2.3. Nevertheless, we agree that the yield can be larger than 2, but a direct comparison of our model results with the measurement based derivation of Wrotny et al. (2010) is not possible for the arguments given above.

(2) Page 5 line 12 - "The equator is chosen for its negligible seasonal cycle." While the equator is a reasonable choice because some seasonal cycles are smaller, the change in H2O entering the stratosphere at the equator is, among other things, certainly not negligible.

We agree with the referee that there are seasonal changes in the H_2O entering the stratosphere (i.e. tape recorder signal), these are taken into account in our set-up, since the MECCA-TAG distinguishes between the transported H_2O and that produced by CH_4. However, our argument for the equator was indeed a bit sloppy. We chose the equator to avoid the polar night, where photochemistry is virtually inactive thoughout long parts of the year.
We deleted the corresponding half sentence in the abstract.

page 5:

Old: The equator is chosen for its negligible seasonal cycle.

New: The equatorial region is chosen for mainly two reasons: (1) the equatorial region is in terms of photochemistry most active and (2) we avoid the inactive photochemistry during the polar night.

Abstract:

Old: We focus representatively on the tropical zone between 23° S-23° N, where seasonal variations are negligible.

New: We focus representatively on the tropical zone between 23° S-23° N.

(3) Page 5 line 29 - is not known should be are not known

Thank you for spotting this. We corrected it!

(4) Page 7 line 6 - once should be at a time.

We changed it as suggested to "at a time".

(5) Figure 5 - The order of the lines in the legend is a bit strange and confusing, being neither high to low nor low to high OH. Please make this easier for the reader.

The legend was indeed confusing. We reorderd the legend accordingly. We also rearranged the legend in Figure 9 in the same manner to save space.

(6) Page 13 line 3 - This short summary paragraph is confusingly written, especially given the use of the phrase on the other hand. Unless Im missing something, increasing OH concentration simply increases the yield of H2O by both the direct and effective measures with the difference between direct and effective being largest at the highest altitudes.

Yes, this is true. We also wanted to explain that the larger difference at higher altitudes is likely caused by the chemical regimes at these altitudes. We like the suggested order and reformulated the paragraph accordingly so that it is easier comprehensible.

page 13:

Old: Summarizing, reduction of the OH concentrations leads to a proportionally larger decrease in the H_2O yield at higher altitudes owing to the differences in the chemical regimes. On the other hand, increasing the OH concentration also increases the direct and foremost the effective yield of H_2O.

New: Summarizing, increasing OH concentrations lead to higher direct and effective H_2O yields. Both yields show when varying OH a larger difference to the reference at higher altitudes, indicating that the sensitivity of the chemical regime with respect to the OH concentration increases with altitude.

(7) Figure 6 - Perhaps I am missing some important point, but it seems to me that this figure and the accompanying text on page 12 is in the section Sensitivity with respect to OH. Wouldnt it be much

more appropriately placed right after the introduction of equation (3), which forms the basis of the terms being plotted?

It is true that Figure 6 and the accompanying text is in the Section 3.1.2., where it does not exactly fit well. It is a very good suggestion to move it next to Equation (3).

(8) Figure 12 - This is an extremely important figure, yet it is plotted on a log scale which makes it difficult to quantitatively determine many of the values of interest. The species could all be put on the same scale with appropriate offsets and multipliers. In particular, it would be interesting to see the H2 variation with altitude in the stratosphere on a linear scale. It is not necessary to show the decrease in water vapor with increasing altitude in the troposphere, so this figure could certainly be started at 100 hPa.

Thank you for pointing this out. We changed the horizontal axis to a linear scale and shifted H by 3.0 ppmv for the sake of visibility. However, we prefer to keep the vertical axis down to 1000 hPa to be comparable with the other plots throughout the paper.

(9) Page 21 line 1 - explicitely should be explicitly.

That is corrected.

(10) Page 23 line 16 - Yet, we see it critical to use the results of le Texier et al. (1988) to justify the approximation of H2O=2 at lower altitudes. I dont understand this sentence.

We wanted to express that we (1) do not recommend to use the approximation of yield=2 at lower altitudes and (2) emphasize that this is, strictly speaking, also not supported by the results of le Texier et al. (1988) although often declared as the reference. We reformulated this sentence to be more precise.

page 20:

Old: Yet, we see it critical to use the results of le Texier et al. (1988) to justify the approximation of H2O=2 at lower altitudes.

New: Furthermore, le Texier et al. (1988) is often cited as the reference for the assumption of γ_{H_2O}=2. However, in the lower stratosphere our results and those of le Texier et al. (1988) actually agree that γ_{H_2O} is less than two, which objects the assumption of a constant γ_{H_2O}=2.

(11) Figure S2 - This figure would be much more informative if the colors were not all red. It seems to me that the color scale could be run from ∼1 to just over 2.

We reduced the scale as suggested. Now some more features are apparent in Figure S2.