

## Authors Response

Dear Reviewer,

we would like to thank you very much for your second review and your list with minor suggestions. Below you find your text with suggestions below "Referee's comments". We applied most suggestions and our answers are given in *blue below the comments*.

Yours sincerely,

Johannes Pletzer

## Referee's comments

### General comments

I see that the authors have invested substantial effort in improving the papers taking into account the comments received from all three referees.

*Thank you for your kind words.*

I still have a few wording clarification suggestions (see below).  
Should these minor points be addressed I recommend publication of the paper.

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P. 1, l. 13: "leading to an increase in H<sub>2</sub>O concentrations." --> increase compared to what?

I suggest two sentences here:

...methane and nitric acid depletion. These processes lead to an increase in H<sub>2</sub>O concentrations compared to a case with no emissions from hypersonic aircraft.

P. 1 l. 14: increase --> increase with altitude (correct?)

p.1: l 16: suggest: 8-22%

p.1: l 17: suggest: 78-92%

*We applied all of the few wording clarification suggestions. Thank you very much for the propositions*

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The paper now contains the following text:

New: "The photochemical depletion of H<sub>2</sub>O and shift to H<sub>2</sub> concentrations (e.g. Fig. 5.23, p. 312, Brasseur, 2005) clearly has no large effect at these emission altitudes. So instead to the expected removal of emitted H<sub>2</sub>O by photochemical depletion, we found a before unknown importance of the reaction rates of the net-recombination of H<sub>2</sub>O based on HO<sub>x</sub> recombination and an increased methane and nitric acid oxidation. Both models show an increase in H<sub>2</sub>O perturbation lifetime and H<sub>2</sub>O perturbation at the higher altitude, which is further increased by the net-recombination, i.e. overcompensation of photochemical depletion. Our finding is robust with good agreement between the two models."

First: do you want to be explicit about the mechanisms of H<sub>2</sub>O by photochemical depletion? You could add the main chemical processes or provide a citation.

We added the most important reactions and referenced them in the text.

Second, I am not sure what "net-recombination of H<sub>2</sub>O based on HO<sub>x</sub> recombination" means. I could imagine that what is meant net production of water vapour based on the (radical recombination) reaction HO<sub>2</sub> + OH and an increased methane (CH<sub>4</sub>+OH) and nitric acid oxidation (HNO<sub>3</sub>+OH) ...

We restructured the description of the process.

Now: "The photochemical depletion of H<sub>2</sub>O and shift to H<sub>2</sub> concentrations (e.g. Fig. 5.23, p. 312, Brasseur, 2005) is clearly not limiting the water vapour perturbation lifetime at these emission altitudes. So instead to the expected removal of emitted H<sub>2</sub>O by photochemical depletion, we found a before unknown importance of water vapour recombination for hypersonic emissions. Several reactions including the hydroxyl radical actually overcompensate the photochemical depletion of H<sub>2</sub>O perturbations. The overcompensation results in a net-recombination (recombination-depletion > 0), that is driven by HO<sub>x</sub> recombination (mainly Eq. 4), an increased methane (Eqs. 5 and 6) and nitric acid oxidation (Eqs. 7 and 8). Both models show an increase in H<sub>2</sub>O perturbation lifetime and H<sub>2</sub>O perturbation at the higher altitude, which is further increased by the net-recombination. Our finding is robust with good agreement between the two models."

as it stands the text is confusing and I think that adding the actual reactions that are most relevant here helps.

(I think the issue is actually better described and discussed in the abstract)

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The following text was added to the paper:

"The middle atmospheric balance of water vapour is determined by methane oxidation, photochemical lifetimes of HOx compounds and tropical upward transport, which is limited by the coldpoint temperature (LeTexier et al, 1998; Brasseur, 2005; Frank et al, 2018). Polar dehydration by polar stratospheric clouds and the sedimentation of the particles contribute to the balance."

First, it is good that the current papers are cited (Frank et al., 2018; Winterstein & Jöckel, 2021). But I do not understand why/how tropical upward transport is limited by the coldpoint temperature. Isn't it the temperature in the lower stratosphere which is relevant here rather than the temperature at one particular point? Alternatively, do you mean that stratospheric water vapour is influenced strongly by the entry value of water vapour? This entry value is indeed influenced by the cold point temperature. But then another wording/explanation is required (see also the cited papers).

Thank you for pointing that out. We changed our choice of words accordingly (underlined).

Now: "The middle atmospheric balance of water vapour is determined by methane oxidation, photochemical lifetimes of HOx compounds and upward transport through the tropical upper troposphere lower stratosphere, which is limited by the cold temperatures (LeTexier et al, 1998; Brasseur, 2005; Frank et al, 2018). Polar dehydration by polar stratospheric clouds and the sedimentation of the particles contribute to the balance."

## References

Brasseur and Solomon, 2005.

-- you cite two editions of this book in the paper  
but I think you need only one citation

Since the last revision our draft should only contain the 2005 version of Brasseur's book. If you would be so kind to explicitly state the line we will correct the citations gladly.

Frank, F., Jöckel, P., Gromov, S., & Dameris, M.: Investigating the yield of H<sub>2</sub>O and H<sub>2</sub> from methane oxidation in the stratosphere, Atmospheric Chemistry and Physics, 18, 9955–9973, doi: 10.5194/acp-18-9955-2018, URL <https://www.atmos-chem-phys.net/18/9955/2018/> (2018)

Winterstein, F. & Jöckel, P.: Methane chemistry in a nutshell – the new submodels CH<sub>4</sub> (v1.0) and TRSYNC (v1.0) in MESSy (v2.54.0), Geoscientific Model Development, 14, 661–674, doi: 10.5194/gmd-14-661-2021, URL <https://gmd.copernicus.org/articles/14/661/2021/> (2021)