

1) General comments

Winterstein et al. investigate the impact of twofold and fivefold CH₄ concentrations in the atmosphere. Their main conclusions are that on one side higher concentrations of CH₄ strongly influence the tropospheric chemistry due to a reduction of OH, which leads also to a longer CH₄ lifetime, and on the other side has a strong influence on the temperature and chemical composition (mainly H₂O, OH and O₃) of the middle atmosphere. They additionally calculate a positive net radiative impact due to the additional CH₄ for the surface climate.

In my opinion the study is an important contribution for the scientific discussion with focus to climate change and impact on atmospheric chemistry. The scientific quality of the study is very good. EMAC is a widely used state-of-the-art chemistry-climate model and absolutely appropriate for this study. The paper is well written and the presentation quality also very good. Therefore it should be published after some minor revisions.

2) Specific comments

In total I think the calculations, discussion and conclusions are very well deduced and explained in the paper. I therefore only have some suggestions, where the authors can decide for themselves if they want to implement them or not:

- I would change the title at least to “Impact of strongly increased methane concentrations for chemistry-climate connections” or even to “Impact of strongly increased methane on atmospheric chemistry and climate”. I don’t like the wording “extreme” because in this case you think it’s an unrealistic scenario, but at least the 2xCH₄ scenario is absolutely possible until the end of this century.
- I don’t know why you put the figures S1 and S2 into the supplement. I would recommend to put these both figures directly into the main part of the paper, because you discuss these figures in the main text and even refer in the captions to this text. The same is in my opinion true for Fig. S5 and maybe also Fig. S6, actually. These both figures are in my opinion absolutely not supplemental, but extremely interesting. Maybe you can put S5 directly into the paper, because you discuss the results of the panels of this figure directly in Sect. 3.2, and let S6 in the supplement.
- In the last paragraph of Sect. 2 the additional simulations to calculate the single radiation impact of CH₄, O₃ and SMV are explained. Maybe you can add here one or two sentences how the diagnostic for multiple radiation calls in submodel RAD works.
- You don’t explain the higher OH mixing ratios in the lower/middle stratosphere (Fig. 4). I think these aren’t a result of the additional H₂O, but rather of your mentioned fact that the reaction CH₄+OH is temperature dependent (page 8, lines 10 to 15). In a cooler stratosphere this reaction is slower. Perhaps you can add one or two sentences in Sect. 3.2, but only if you agree.
- In the conclusions you mention on page 13, line 13 the ozone columns. Please add this figure into the supplement or alternatively don’t mention the ozone columns, but instead the stratospheric ozone as shown in Fig. 7.
- Maybe you can summarize in the conclusions your results of Sect. 3.2 with regard to the middle atmosphere and the relation of CH₄, H₂O, OH, O₃ and temperature slightly more detailed as on page 13, lines 12 to 14.

3) Technical corrections:

Page 1, line 2: I would recommend to change „a chemistry-climate model (CCM)“ to „the chemistry-climate model EMAC“

Page 1, line 6: “pollutants” → “substances”

Page 2, line 11: “oceans ,” → “oceans,”

Page 2, line 21: “by” → “due to”

Page 3, line 2: “to increase of CH₄” → “caused by the increase of CH₄”

Page 3, line 16: Please delete “which is described in this paper”

Page 4, line 12: “being” → “of”

Page 4, line 13: “being” → “of about”

Page 4, line 20: “online simulated emissions” → “emissions of other trace gases”

Page 4, line 23: “employed” → “used in submodel RAD”

Page 4, line 23: “in a separate additional simulation” → “in separate additional simulations”

Page 4, line 24: “The simulation” → “Each simulation”

Page 4, line 25: “and uses climatological 20 year means of the species of interest, namely CH₄, O₃ and SWV” → “and uses the climatological 20 year means of the species of interest (namely CH₄, O₃ and SWV) from the corresponding reference or sensitivity simulation (REF, S1 and S2)”.

Page 4, line 30: “The reference simulation REF is set up to represent conditions comparable to the near-present atmospheric conditions in 2010.” → “The setup of the reference simulation represents the near-present atmospheric conditions of 2010.”

Page 5, line 9: “based” → “based on”

Page 5, lines 9/10: “in the simulation data as well” → “in all simulations” or “in our performed simulations”

Page 5, line 10: “The simulated gradient of the model” → “The simulated CH₄ gradient of the REF simulation”

Page 5, line 10: “during” → “from”

Page 5, line 19: “zonally averaged CH₄ mixing ratio above the tropopause of REF is done” → “the zonal mean of CH₄ from REF above the tropopause is done”

Page 5, lines 22/23: no line break here

Page 5, line 23: “Our simulation” → “Our REF simulation” or “The REF simulation”

Page 5, line 25 (or line 4?): “turned out to be sufficient for” → “is suitable for”

Page 7, line 3: I think the unit for the reaction coefficient is cm³s⁻¹ instead of s⁻¹

Page 8, line 10: “relatively strong relative depletion” → “relatively stronger depletion”

Page 9, line 10: I would insert here a sentence like: “The additional H₂O leads to increasing OH in the upper stratosphere and lower mesosphere (Fig. 4).”

Page 10, line 1: “-1 - -2 K” → “-1 to -2 K”

Page 10, line 5: I would insert here a sentence which describes the relation between the O₃ depletion in the upper stratosphere/lower mesosphere (Fig. 7) and the additional cooling.

Page 10, line 18: “Excited” → “excited”

Page 11, line 11: “... fivefold case (S2).” → “... fivefold case (S2) (see Table 1).”

Page 11, line 18: “(see 2)” → “(see Sect. 2)”

Page 12, line 12: “1750 (pre-industrial) to 2011 has led” → “650 ppbv (pre-industrial) to 1750 ppbv (2011) has led”

Page 12, line 17: “The stratosphere cools by about -1 - -2 K” → “The stratosphere additional cools in S1 by about -1 to -2 K”

Page 12, line 20: I don't see this pattern: “warming in the lower stratosphere, cooling in the middle stratosphere, warming in the upper stratosphere and cooling in the mesosphere”, maybe rather: “warming in the troposphere, cooling in the lower/middle stratosphere, less cooling in the upper stratosphere and stronger cooling in the mesosphere”

Page 13, lines 13/14: Here you discuss a new result: “In particular it will lead to an increase in total O₃ column (not shown) nearly on the whole globe. Only in the antarctic spring it causes a strengthening of the ozone depletion.” Please integrate this figure either into the paper or at least in the supplement. I also would recommend to discuss this already in Sect. 3.2 after the O₃ paragraph.