

Comments for Paper entitled “Sensitivity of climate effects of hydrogen to leakage size, location, and chemical background”

This paper investigates the impacts on H₂ and CH₄ GWP100 due to changes in three different scenarios settings. These settings are : 1) changes in hydrogen emission perturbation, 2) pulse emissions of hydrogen at specific locations, and 3) three different SSP scenarios. They find that the H₂ GWP100 does not depend on the magnitude of hydrogen emission perturbations. For specific locations of H₂ emissions, the H₂ GWP100 is different in locations far from soil uptake e.g. in the ocean and in Antarctica. For different SSP scenarios, the H₂ GWP100 is dependent on both CH₄ concentration and the NO_x:CO ratio, both of which heavily influence OH and, by extension, H₂ atmospheric lifetime and GWP100. Ultimately, however, the soil sink is the dominant driver factor for H₂ soil rather than the H₂ atmospheric lifetime. With the exception of the pulse experiments located in the ocean and Antarctica, all H₂ GWP100 results are within one standard deviation of the GWP100 found in Sand et al. (2023).

This is a comprehensive study assessing the GWP100 of H₂ under different situations. Hydrogen is an important topic in both in research and society and this is a valuable contribution to the hydrogen community in narrowing down the uncertainty of H₂ and its impact on the climate.

General comments

- Some of the results would benefit from further quantitative analysis to state whether these values are statistically significant (see comments below).
- I think the authors need a further explanation as to why they've chosen their locations and to define what is meant by a “sink soil active area” as this is unclear to me.
- Given that the authors have described how interconnected the reactions are in the atmosphere, would be useful to have a forth experiment where both the H₂ emissions and the CH₄ concentration is enhanced. This would then clarify whether the enhancement due to H₂ emissions and CH₄ concentration is additive or if increasing both CH₄ and H₂ causes an further increase due to OH production/loss e.g. anthro1 for H₂ and 10% increase in CH₄ for present day. Author may have already taken this into consideration, in which case this should be clarified in the text
- The conclusion of linearity between GWP100 and H₂ emission perturbation is currently misleading and confusing, especially as authors later say these two variables are independent. From Fig 3 it is difficult to see how these are linear as well

Specific comments

Abstract

lines 9–10 : This sentence is vague – specify the reactions (OH induced) and what the effect on CH₄, O₃ and H₂O are

Line 14 : See later comments about linearity of GWP100 + size of emission perturbation. Also, if it is linear, this is only true when you consider the magnitude of emission perturbation as the emission perturbations chosen are logarithmically increasing
Line 20 : This is a strong statement and as you point out in the conclusions it isn't taking into account soil sink. Can you add a clause that this is only considering OH sink of H2?

Introduction

line 25 : Specify how it will cause these greenhouse gases to change
line 44 : Missing refs. Either add more in, or give e.g.

Methods

line 75 : expand full model acronym at first instance
line 80 : Does the third experiment also have enhanced H2 emissions along with an enhanced CH4 concentration? Adding a sentence in to clarify would help this.
Line 86 : Merge into previous paragraph
Line 87 : Define what is meant by linearity here – if the emission perturbations are increasing by a magnitude of 10 in each experiment, “linearity” is misleading here unless you specifically refer to the logarithmic increase of perturbations
Line 87 : In line 79, the authors say they run 3 simulations to calculate GWP, and here they explain they have 3 sets of sensitivity tests (which include multiple simulations). I assume these are separate to the GWP runs described previously? Please could the authors add in a few sentences at the start of the methods section to summarise all the set of experiments they're doing more clearly. Authors might consider moving the “GWP Calculation” section to after the “Sensitivity experiments” (after Lines 103–109) have been explained to help with layout of explaining their experiment setup
Line 100 : “correspond to two different control simulations, as hydrogen is concentration driven in the methane perturbation simulation.” Please expand on the differences between the control simulations.
Line 113 : “The OsloCTM3 model is used in a similar set up as in Sand et al. (2023)” Please give a brief description of what the set up is here.
Line 120 : Authors might consider using the corrected oceanic H2 emissions from Paulot et al. 2023 (Fig S3)

Results

Section 3.1: The title of this section is quite ambiguous at a first glance. Please could the authors rename it to be more informative
Line 163 : Similarly, in this sentence could the authors clarify “the results” (I assume they mean the H2 GWP100 values from the previous section?).
Line 165 : It's difficult to see how the GWP100 values have a linear relationship wrt magnitude of emission. The anthro100 GWP actually looks like it is lower than the anthro10. These values are very close together – can the authors say whether or not these are significantly different enough for it to be considered linear?
Line 178 : How do the authors define an soil sink active area? Is it based on the average soil uptake over an area?
Line 180 : Can the authors show these differences are statistically significant from one another? I think this would strengthen their argument

Line 185 : Referring to Fig. 1b at the end of this sentence is somewhat confusing as the numerical values (5.2 and 5.4) refer to Fig. 4a. The authors could move this Fig reference to a more suitable place in the sentence or leave it out entirely.

Line 195 : Could authors give an equation for the feedback factor than rather a word description and also define lifetime of perturbation for a complete explanation

Line 204 : Can the authors expand more on what is significant of the lowest feedback factor being 0.76 would mean in the larger context?

Line 201 : There doesn't look like there is much change in forcing if there is an increase in H₂ burden from Fig 4. and all the GWP values are similar. Are these statistically significant values from each other to make this statement? Authors say that it is within the uncertainty range of values from Sand et al. 2023 so perhaps not?

Line 236 : Worth mentioning that the dominant chemical loss of H₂ is via OH and/or refer to equation 1

Line 240–253 : This is nicely explained

Line 253: Can authors comment on the effectiveness of NO_x: CO ratio and changes in CH₄ of H₂ lifetime?

Line 174 : Can authors suggest why the ozone contributes are greater in SSP119 than the others? Or is it that the ozone contribution is the same in all scenarios, but the contributions from strat. H₂O and CH₄ are lower in SSP126, resulting in a large proportion from ozone?

Line 297 : I might be misunderstanding this, but earlier in lines 163–6 authors say results are linear (which is unconvincing from the graph), but also say they are independent with respect to the magnitude of emission perturbation. These two conclusions seem mutually exclusive. Can authors describe what they mean by “independent” of hydrogen emission perturbation, but have a “linear response”?

Line 306 : Can authors clarify how the longitudinal dependence links to soil sink active areas (e.g. inland vs by the coast?)

Line 315 : Given that the authors are looking at particular locations, it's not surprising that GWP values are outside the standard deviation values from Sand et al., especially as these are at the extremes which won't be captured in a standard deviation range.

Consider rephrasing the sentence 314–316 so it is less defensive of this result!

Line 335 : Rephrase to “lifetime decreased by a range of 0.19–1.1 years” or equivalent

Line 368–9 : Can authors rephrase this sentence to include quantitative values to support their argument?

Line 370–1 : “due to process understanding of the hydrogen budget.” I assume the authors specifically mean the soil sink budget?

Table 2 : State what the starting concentration is for CH₄ concentration in present-day without 10% increase

Fig 1b : Could the authors also provide a figure of soil deposition in units commonly used in other papers e.g. cm s⁻¹ so it can be compared to other soil deposition models (e.g. Paulot et al. 2021, Bertagni et al. 2023).

Fig 2a: I assume the authors mean the surface methane concentration – can you add this into the caption for clarity

Fig 3: Are these values averaged over one year or multiple years?

Technical comments

line 56 : NO_x vs NO_x

line 68 : “as well *as*”

line 86 : Combine sentence with previous paragraph

line 87 : First sentence is a repeat from paragraph before – remove

Fig 1b: Move the caption or change the colour in the high northern latitudes as it is difficult to read

Table 1: missing “s” in “magnitude of the emission perturbation”

line 276 : Missing % after 3.0

line 296 : No need to reference Sand et al. At the end given the start of the sentence

line 360 : NO_x vs NO_x

line 370 : process → processes