Reviewer #2

General Comments

The paper examines the facilitation and inhibition of CO2 uptake throughout the entire duration of a peak-shaving deployment of SAI. A three-member ensemble simulation of SSP5-3.4-over is compared against SSP5-3.4-sulfur in CNRM-ESM2-1+. The paper finds finds that although there is an enhancement of the carbon cycle during the early phases of the deployment, the later phases see a decline in enhancement, eventually becoming an emission burden in the final phases of peak-shaving and in the years after deployment.

I believe that this paper has valuable contributions and makes some excellent points about the impermanence of SAI's carbon cycle enhancement in a peak-shaving scenario. However, there are portions of the paper in which the language can be imprecise, and the points made are overreaching. In particular, the paper states that phasing out SAI may be made less desirable or more difficult by the burden incurred in the later phases. This statement seems to make certain assumptions about the scenario. In particular, either it assumes that those in the scenario take advantage of the entirety of enhancement provided by SAI in the early stages and ignore that some of SAI's carbon benefit is temporary, or it assumes that those doing CDR in the scenario care more about smaller rate of carbon removal they can do in the later phases than the smaller amount of carbon removal they must do in the later phases.

In all, I believe the science of this paper to be very good, but it draws conclusions from its findings in a way that should be revised.

We thank the reviewer for their valuable comments and recommendation for publication if major points are addressed. We are going to modify the paper to exclude any statements regarding a scenario's desirability, since it is ultimately a value judgement and, as the reviewer points out, makes assumptions on the scenario. We are going to add more clarity on the temperature baseline, add details to plots, add an additional paragraph on the areas above and below 0 land and ocean carbon uptake and other little corrections and clarifications the reviewer kindly pointed out.

We hope that our modifications will address the reviewers' concerns and thank them for a second screening of the paper.

Specific Comments

1. Some notes around the concept of making phasing SRM out more difficult:
    1. Line 92: Prolonged SRM deployment and higher CDR in response to sink degradation are a sliding scale, not necessarily an "and". For

example, higher CDR to exactly offset the source in phase III of SSP534-sulfur would result in the same phase out, if I'm understanding correctly.

We are going to add an "or" to emphasize that a sink degradation would prolong SRM deployment **or** require larger amounts of CDR to compensate.

2. The statements (e.g. Line 382) that the phase-out of SAI may be made "undesirable" can be further developed, as certain assumptions about those desires can be be made explicit.
    1. If the global community uses up the extra CO2 budget gained from the early phases of peak-shaving by either not mitigating or doing less CDR, then would they have the CO2 concentrations of SSP534-over and thus an extra burden on the tail end. It is relatively clear how the people of Phases II and III might not want to ramp up CDR more than they would have had to.
    2. A less clear example is that if is if they mitigate and do CDR in Phase I as they would have in the baseline SSP534-over case, then they would have lower CO2 concentrations in Phases II and III. They would need more CDR for the same CO2 removal during these phases, but they would also have less CO2 to remove (in net, 60 Gt less). If the speed at which carbon cycle draws out CO2 is the primary desire, they would find difficulty, but if they value getting the CO2 concentration back down to a certain level while maintaining a certain temperature (the premise of peak shaving), I struggle to see how phasing out SAI would be made more undesirable.

The reviewer lists some interesting scenario logics. Our thought process following the results is: Carbon uptake under SAI throughout the peak-shaving period varies in a way that SAI enhances the already pre-existing effect in overshoot scenarios where reducing atmospheric CO2 concentration is "easier" before net-zero CO2 and "harder" afterwards. Therefore, regardless of whether the additional CO2 budget is taken advantage of in the early stage or not, the additional outgassing under SAI after net-zero makes atmospheric CO2 reduction "harder" in later stages.

With SRM keeping temperatures at a comfortable level and CDR becoming harder, we concluded that this may make SRM phase-out less desirable than for example in an overshoot scenario where no peak-shaving is happening. We recognize that this is a subjective statement and are going to entirely remove the framing of "desirability" from the paper.

However, despite desirability, our conclusions are independent of whether the additional carbon uptake benefit is leveraged or not. Therefore, we refrain from discussing any potential scenario outlooks or assumptions regarding the "use" of the additional carbon budget.

Lines 324-328 / Figure 3: the extra 38 GT of CO2 burden seems like it would be less than two years of extra CDR as modeled in ssp534-sulfur, ending in 2152 instead of 2150. While I agree with the "non-negligible" statement with respect to CDR that exists today, the CDR in the paper's scenarios far outpace the examples the paper gives. This should be at least addressed.

We are going to add a sentence in L. 328 along the lines of "However, compared to the annual CDR assumed in the scenario, these additional CDR efforts appear less substantial"

2. Line 21: The concept of "buying time" during peak shaving usually refers to time it takes halt temperature rise and reduce it again, and the risks incurred during that temperature peak. It does not usually refer to the extra help from carbon cycle enhancement.
    1. E.g. Zarnetske PL, Gurevitch J, Franklin J, Groffman PM, Harrison CS, Hellmann JJ, Hoffman FM, Kothari S, Robock A, Tilmes S, Visioni D, Wu J, Xia L, Yang CE. Potential ecological impacts of climate intervention by reflecting sunlight to cool Earth. Proc Natl Acad Sci U S A. 2021 Apr 13;118(15):e1921854118. doi: 10.1073/pnas.1921854118. PMID: 33876741; PMCID: PMC8053992.

The "buying time" concept has different interpretations with the most common one being to "reduce pressure" of implementing adaptation and mitigation.

"Insofar as SAI combats the worst impacts of peak global CO2 emissions, it buys time for different climate approaches that might take longer to show effect, such as mitigation, adaptation or other CDR measures. SAI, as a stop-gap measure with quick results, reduces pressure for implementing other adaptation and decarbonization strategies. It is this reducing pressure framing that seem to lie at the heart of the many versions of buying time or peak-shaving arguments." Neuber & Ott, 2020 (https://www.mdpi.com/2076-3417/10/13/4637)

3. The difference in compatible emissions do not seem linked to the three phases of SAI deployment specifically, considering the crossover at 2100. Looking at 3b and 4a (for land at least), it looks as though under SSP534-sulfur, the sink becomes more of a sink and the source becomes more of a source. To say in line 377 that the uptake is increased during SAI roll-out but decreased during phase-out feels off, since it seems to have more

to do with when it's a source or sink, and thus the background GHG emissions pathway and the CO2 concentrations.

    1. In other words, would phasing out SAI while doing no CDR cause the negative difference starting at 2100 in Figure 3b? Alternatively, would not phasing out SAI and maintaining a constant amount of cooling while doing the same amount of CDR as simulated create the 2100 crossover?

We agree with the reviewer that the response of the land reservoir does not correlate directly with the stages of SAI deployment. We are going to change the framing of the sentence in L. 377 and throughout the paper to make clear that while the C uptake is enhanced when land acts as a sink, it is reduced when land acts as a source. However, the primary mechanism of whether it is a sink or driver depends on the CO2 concentration, not SAI.

4. Line 26: Although CO2 removal is often considered a form of mitigation (IPCC AR6 WGIII: CDR Factsheet), it is also often considered separate from mitigation (e.g. NASEM, 2021: "This portfolio must involve reducing GHG emissions to the atmosphere (mitigation), and removing carbon from the atmosphere and reliably sequestering it"). This paper should explicitly state whether it is defining mitigation to include CDR or considering CDR to be independent, cite a source to support that definition, and then stick to it for the duration of the paper.
    1. I would recommend separating the two, such that something like the first line of the abstract "...allowing additional time for the implementation of conventional climate mitigation strategies and CO2 removal." could be read without confusion, regardless of whether the reader defines CO2 removal as mitigation or not.

We thank the reviewer for pointing this out and will add a sentence in the introduction clarifying our definition of what counts as mitigation. We are going to go with the denomination of the latest IPCC report, that classifies CDR as a form of mitigation (Riahi et al., 2022).

5. Lines 37-78: Be clear about the baseline that the paper is comparing SAI to with each comparison. For example, the CO2 fertilization effect is likely to the same temperature, no-SAI, but the reduced heat stress is likely to the same CO2 concentration or year, no-SAI.

We agree that this is important, as highlighted in L. 292, and are going to include the baselines to the comparisons.

6. Line 100: Regarding "increase of 2°C", say relative to what baseline (pre-industrial, but also discuss how are it is being defined)

We will add details on the definition of our temperature baseline.

7. Line 117: The paper should give SSP126 the same background as it gave SSP534. At present, it is put into the text without definition.

We disagree with the reviewer's judgment here since our scenarios have nothing to do with the SSP126 storyline itself and no comparisons of our simulations with a SSP126 pathway are made. We are going to add the words "the global mean radiative characteristics of a SSP126 pathway" in L 117 to add clarification.

8. Figure 3b: I am curious about the total area over 0 and under 0 (which sum to be 60 Gt), especially since there seem to be two "phases": where the difference is positive going until ~2100 and where it is negative after.

We are going to add a short paragraph in the Discussion where we quantify separately the area over and under 0, since they can be easily separated into 2 phases (before 2100, after 2100).

9. Figure 3b: It would be nice to have a measure of variability – what is significant difference between compatible emissions vs. what is a byproduct of variability.

Yes, agreed. We are going to add a measure of the spread around the mean difference to the plot.

10. Figure 4: Some sort of Carbon sink vs. Temperature plot may be useful here. Masking temperature by land and ocean could be included, or use cooling done by SAI vs. difference in sinks, but given that peak-shaving SAI is about control of temperature, it may be enlightening to see what effect it has (or does not have) on the sinks.

We will add temperature on a second y-axis to 4a.

11. Line 253-254: Cite Trisos et al. 2018 or similar paper about the effects of termination shock when talking about a sudden cessation of SRM having different impacts.

    1. Trisos, C.H., Amatulli, G., Gurevitch, J. *et al.* Potentially dangerous consequences for biodiversity of solar geoengineering implementation and termination. *Nat Ecol Evol* **2**, 475–482 (2018). https://doi.org/10.1038/s41559-017-0431-0

Ok, will do.

12. Line 332: Not necessarily disagreeing with "SAI is not CDR," but this statement is a little unclear. Will the net 60 Tg carbon benefit become net 0 Tg

eventually? If so, then highlight this. If not, then some of SAI's CO_2 removal is permanent, if limited. It is worth noting that the paper says in Line 325 that amounts of CO_2 of similar magnitude to 60 Gt are "non-negligible."

Our point here is more along the lines of land carbon uptake from SRM not being a permanent and safe storage (in comparison to geological uptakes or MRVed biomass carbon removal). We are going clarify our statement in the text.

13. Line 359: Cirrus Cloud Thinning is technically not Solar Radiation Modification.

While we agree with the reviewer that CCT is strictly seen not SRM, it is usually categorized under Solar Radiation Modification / solar geoengineering approaches, even by the IPCC (Lee et al., 2021).

Technical Corrections

1. Line 20: 1.5°C -> 2.0°C

Thank you, we are going to correct it.

2. Line 26 / Line 92: CDR is never defined to be CO_2 Removal or Carbon Dioxide Removal; it appears for the first time in line 92.

Thank you for pointing this out. We are going to introduce it in Line 26.

3. Line 33: Injections -> Injection, enhance -> enhances

Ok, we will change it.

4. Line 47: Sur- face

Ok, we will change it.

5. Line 62: "the major levers" feels informal -- consider different phrasing

We are going to change "major levers" to "principal drivers"

6. Figure 1a: mention pre-industrial somewhere (perhaps Y-label or title)

Title changed to "Warming since pre-industrial"

7. Figure 1b: X-label – Years->Year

Ok.

8. Figure 2: mention pre-industrial somewhere (perhaps Y-label or title)

Title changed to “Warming in SSP534-over since pre-industrial”

9. Line 181: The-> the

Since the colon introduces a complete sentence, the first letter is capitalized.

10. Line 195: be- tween

Ok.

11. Line 241: are -> is

Yes, corrected, thank you.

12. Line 251-253: “Hence their call . . . under SRM” is a sentence fragment.

We will add a semicolon before “Hence” and a comma after “Hence”

13. Line 377: “a third *comes* from the ocean.”

Thank you, we corrected it.