Peer Review: Tang, et al. 2023, <u>Impact of Solar Geoengineering on Wildfires in the 21st Century in CESM2/WACCM6</u>

General Comments

This study investigates whether and how solar geoengineering affects wildfire impacts in CESM2 simulations by examining the major contributing factors to wildfire activity and how they change in response to geoengineering. The authors find that, in most regions, solar geoengineering causes reductions in wildfire activity, largely due to reduced surface temperatures and increased relative humidity and soil moisture, despite reduced precipitation.

Overall, this is a sound study with meaningful results, and reading it was interesting and informative; wildfires are an important aspect of the climate system, and a study about how solar geoengineering does or does not offset possible changes under global warming is an important contribution to the literature. However, the manuscript needs some work before it can be published. I have two major criticisms. Firstly, the authors need to clarify their methods in some areas; it is not always clear how the authors computed certain numbers presented in their results, and the authors should explain more clearly whether they are averaging over a certain period or how they accounted for certain factors when computing statistics. Secondly, many of the figures are unpolished or incomplete, with missing uncertainties, ensemble spread, or statistical significance; inconsistent color schemes; frustrating or confusing color scales; and captions that do not fully explain how data are calculated. Correcting these issues would improve the clarity, ease of reading, and repeatability of the study. Specific comments and technical corrections are listed below, and I recommend that the study be accepted with minor revisions so that these findings can be published.

Specific Comments

<u>Abstract</u>

- Lines 37-38: “a global reduction in burned area and fire carbon emissions” is somewhat misleading; solar geoengineering reduces these relative to SSP5-8.5, but burned area does not appear to be meaningfully reduced relative to present day

<u>1. Introduction</u>

- Lines 92-94: I was unable to find in Robock (2020) where he says that controlling for temperature overcompensates for changes in the hydrological cycle; he just mentions that GLENS "does not show that precipitation and temperature can be controlled at the same time". The following might be better citations here:

- ○ Lee, et al. (2020): Expanding the design space of stratospheric aerosol geoengineering to include precipitation-based metrics and explore trade-offs, Earth System Dynamics, doi:10.5194/esd-11-1051-2020
- ○ Tilmes, et al. (2013): The hydrological impact of geoengineering in the Geoengineering Model Intercomparison Project (GeoMIP), JGR Atmospheres, doi:10.1002/jgrd.50868
- ○ Bala, et al. (2008): Impact of geoengineering schemes on the global hydrological cycle, PNAS, doi:10.1073/pnas.0711648105

- Lines 101-102: You should elaborate on how important this feedback is (or isn't), so readers unfamiliar with fire schemes can get a sense of how meaningful the results are, and how much an improvement to the model to include this feedback would (or wouldn't) improve your results

2. Model Description

- Lines 128-129: "Agricultural fires" refers specifically to fires intentionally set for agricultural reasons, correct? If deforestation fires are also intentional, why are they included?
- Lines 186-188: This is globally-averaged forcing, correct? Additionally, the wording "going from 8.5 W/m^2 to 4.5 W/m^2 by 2100" is a bit confusing. I would clarify - "Both of these geoengineering scenarios aim to reduce globally-averaged forcing from the ScenarioMIP Tier 1 high-forcing scenario (SSP5-8.5), which averages 8.5 W/m^2 of forcing by 2100, to the medium-forcing scenario (SSP2-4.5), which averages 4.5 W/m^2 of forcing by 2100." Additionally, you should clarify whether the goal of each experiment was to match the forcing directly (e.g., 8.5 W/m^2 → 4.5 W/m^2) or to match the surface temperature (e.g., surface temperature of 8.5 W/m^2 → surface temperature of 4.5 W/m^2).
- Lines 194-196: Can you elaborate on the feedback algorithm at all, for the benefit of those unfamiliar with it? Even one more sentence, such as "The feedback algorithm chooses the reduction in solar constant or SO_2 injection quantity based on the prescribed goals, and it adjusts this quantity each year to correct for differences between the simulated climate state and the target" would be helpful.
- Lines 201-202: I was looking for the horizontal resolution back in 2.1, where you gave the vertical resolution of WACCM; consider moving it there

- Lines 203-204: Whenever you direct someone to the supplementary, I recommend including exactly what they should expect to find. Right now you have “see Table S1”; I suggest changing to “see Table S1 for ensemble sizes” or similar

3. Results

- Line 211: I’m guessing that all your numbers in parentheses are averages for the 2091-2100 period relative to the 2021-2030 period. You should say this explicitly
- Lines 215-216: It would be helpful if you could include some context about why burned area is expected to decrease in some regions under some scenarios; this is certainly explored in-depth later in the paper, but for a first-time reader, one sentence here - “while total burned area is expected to increase under most global warming scenarios, burned area may decrease in some regions due to reduced 2m relative humidity and reduced soil moisture” or similar - would be very helpful.
- Line 231: Do the ranges represent ensemble spread? You should clarify your methods explicitly

4. Mechanisms

- Lines 296-297: “The correlations calculated here account for spatial variability within the region and interannual variability during 2091-2100” How, exactly? Please say explicitly what you did to account for this
- Lines 307-308: “This suggests that the changes in area burnt in these regions are not predominantly driven by the surface temperature changes, but by other factors” This seems like an odd speculation to make, given that the purpose of your study is to determine how geoengineering affects fires - do your results support this, or not? This also contradicts what you say in the discussion, which is that these regions are not very sensitive to any of the factors considered in this study
- Lines 349-352: If you’re going to discuss this analysis, you should provide the actual numbers, either here or in the supplementary
- Lines 371-374: Does the model output support this? It should be relatively easy to compute evapotranspiration and confirm or deny this
- Lines 465-468: I disagree with this sentence; G6Solar does not provide more “direct” climate impacts than G6Sulfur, and it does not follow that G6Solar would therefore be expected to have larger impacts, as both experiments have similar reductions in downward forcing and surface temperature

- Lines 468-470: Without shading or error bars in the figure, there is no way to know whether or not the differences between G6Solar and G6Sulfur are significant

5. Conclusions

- Line 535-537: Be careful with wording; burned area decreases in the geoengineering scenarios relative to SSP5-8.5, but there is no decrease relative to present day, or SSP2-4.5, that is statistically significant in Fig. 1

Figures

- Figures 1, 2, and 4: I would like to see uncertainty better represented in these figures. Ensemble spread is missing for SSP2-4.5 in Fig. 1a and 1c, for SSP2-4.5 and SSP5-8.5 in Fig. 1b and 1d, for all simulations in Fig. 2b and 2d, and everywhere in Fig. 4. For time series, I would like to at least see the ensemble spread; ideally, the uncertainty introduced by taking the 5-year running average would also be accounted for. For plots showing a difference between two time periods, the uncertainty for both the experimental period and the reference period should be reflected.
- Figure 1: I suggest flipping the axes for panels b and d (latitude, the independent variable, on the horizontal axis; burned area or C emissions, the dependent variables, on the vertical axis).
- Figure 1: The “10^4” for panel b (At least, I think it belongs to panel b and not d) is very out of the way - I suggest making it easier to find, perhaps by including it in the axis description: “Burned Area (10^4 km^2/yr)”
- Figure 1: According to Table S1, SSP2-4.5 also has multiple ensemble members; why isn’t there shading to show the ensemble spread like there is for SSP5-8.5? Why isn’t there shading in panels b and d at all?
- Figure 2: Same comment as above about 10^4 for panel b
- Figure 2: The color scheme should be consistent with Figure 1. SSP2-4.5 and SSP5-8.5 were red and purple in Fig. 1 and they’re blue and black in Fig. 2. Using the same colors for each run throughout the paper would be very helpful
- Figures 3, 5, and 7: I would like to see statistical significance on all of these maps, i.e., hatching or shading where the changes are not significant.
- Figure 4: same comment about color scheme consistency across figures
- Figure 5: for the temperature plots, I strongly recommend a different color scheme. For every other plot in this figure, yellow represents no change, but on the temperature plots,

both red and blue represent cooling, and yellow indicates moderate cooling. This is quite confusing; I suggest either changing the limits of the color scheme from +8 to -8 to match the other plots, with red for warming, yellow for no change, and blue for cooling (even though there's no warming), or keep it from 0 to -8 and have the color scale just be yellow and blue. Either way, I advise no red on the temperature plots if there's no warming!

- Figure 5: for precipitation, humidity, and soil moisture plots, by convention, red is usually used for drier conditions and blue for wetter conditions. I recommend you flip the color scale
- Figure 6: This plot is very hard to read, for two reasons: firstly, all the panels have different color scales, and secondly, the different shades of yellow and orange blend together and make it hard to search for a specific result. I recommend you change the color scheme to be more like Figure S5; that plot uses a consistent color scheme for the entire figure, and the contrasting blues and reds make it much easier to identify patterns.
- Figure 7: see previous comments on plots in Fig. 5; here, red = warming and blue = cooling, and this one is much easier to interpret. Same comments about the hydrological plots
- Figures 8-9: I assume that all "changes" refer to 2091-2100 averages? You should say this explicitly in the caption
- Figures 8-9: Some of the number labels are covered up by other data points; can you fix this?

Technical Corrections

- Lines 183-196: This could probably all be one paragraph
- Lines 223-224: "the fire carbon emissions and burned area generally show trends consistent with burned area" I think there's a typo in here
- Line 470: There is no Figure 4g; I assume you mean 4f?
- The "Conclusions" section is mistakenly numbered "4" instead of "5"
- Figure 8: I think there is a typo in the caption, line 994; I believe "G6Solar" should be "G6Sulfur"