Reviewer #1

Baur et al. evaluate the potential for solar photovoltaic and concentrating solar power under three future climate scenarios: SSP5-8.5, SSP2-4.5, and G6sulfur which reduces the climate forcing from SSP5-8.5 to SSP2-4.5 using stratospheric aerosol injection (SAI). They find the resource potential for both technologies reduces under the geoengineering scenario. The results confirm the one study that has previously investigated SAI impacts on solar energy technologies, from Smith et al. (2017).

The study is a development over Smith et al. (2017) in two regards. Firstly, the authors consider locational feasibility of solar power installations, ruling out or downweighting grid cells that are in protected areas, far from population centres, and conflict with existing land use types. The second is that the authors consider the intra-year variability in solar energy resource, referring to “low energy weeks” in which meteorological conditions do not produce sufficient energy. I also quite like that the authors used hourly data output from the climate model (compared to three-hourly from Smith et al.). With these additions, the results are similar to Smith et al. (2017), indicating robustness in the (admittedly intuitive) statement that SAI leads to reduced solar energy potential. Given the increasing occurrence of SAI in policy discourse, it is important that studies like these get a renewed focus, as the negative impacts on conventional mitigation (e.g. renewable technologies) of geoengineering are often not considered.

We appreciate the reviewer’s comments and are pleased to hear that they find the study to be a valuable contribution to the SRM discourse.

Main comments:

1. There does not appear to be a consideration of the solar geometry in the equation for PV. For CSP, the factor of the cosine of the zenith angle cancels out (Smith et al. eq. (7), eq. (9)) so providing the FLH equation is correctly defined in your paper then this is OK. However for PV, the direct/total irradiance is important, as well as the orientation of the solar panel, as to the amount of radiation it receives and the panel temperature which affects its efficiency. In eq. (1), the power output expected would be greater than predicted from the climate model value of RSDS, since this would be a horizontal irradiance value, and a real-world solar plant operator would angle the panels appropriately to maximise the incident irradiance on the panel. Perhaps these corrections are already baked into the equations you use. It would be good to confirm.

We agree that the consideration of the solar geometry and the exposition of the panels is a better representation of real-world solar farm installations. In our revised manuscript we added another subchapter to the methods and results showing PV potential when solar geometry and panel inclination are accounted for and discuss these additional results in the following parts of the paper. Unfortunately, we could not update the entire analysis of our study because a processed decomposition of the single physical drivers (Figure 3) is not possible for us under separation of direct and diffuse light (the model doesn't produce the RSDSdiff-clear-sky variable as a standard output).

The main conclusion of the paper does not change with this updated version of the PV potential calculation but it shows even larger relative and absolute reductions in the high latitudes than for horizontally aligned panels (Figure 1). This is because the tilt of the panel increases the amount of direct radiation that can be harvested. However, SAI modifies the fraction of direct and diffuse radiation to entail a larger diffuse fraction and therefore the advantage of the tilt is reduced under SAI versus the SSP scenarios. Hence, relative reductions in high latitudes under SAI that already exist for horizontally aligned panels are further increased for tilted panels.

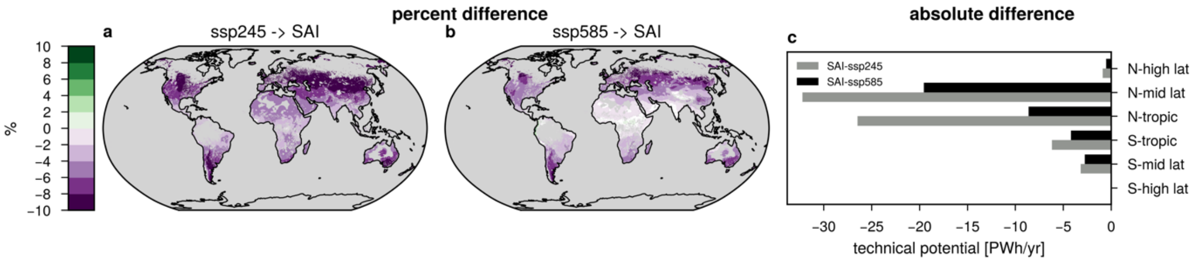

Figure 1: Difference in 2090-2099 PV potential with fixed tilted panels between the ensemble means of SAI and a) SSP245, b) SSP585 and c) absolute difference between latitudinal zonal sums between SAI and SSP245 and SSP585 in PWh/year. White areas have a SNR of < 1. x -> y denotes (y – x)/x.

We added a figure to the Supplementary Information to illustrate the effect of the tilt and solar geometry on the direct and diffuse radiation that reaches the panels surface (Figure 2).

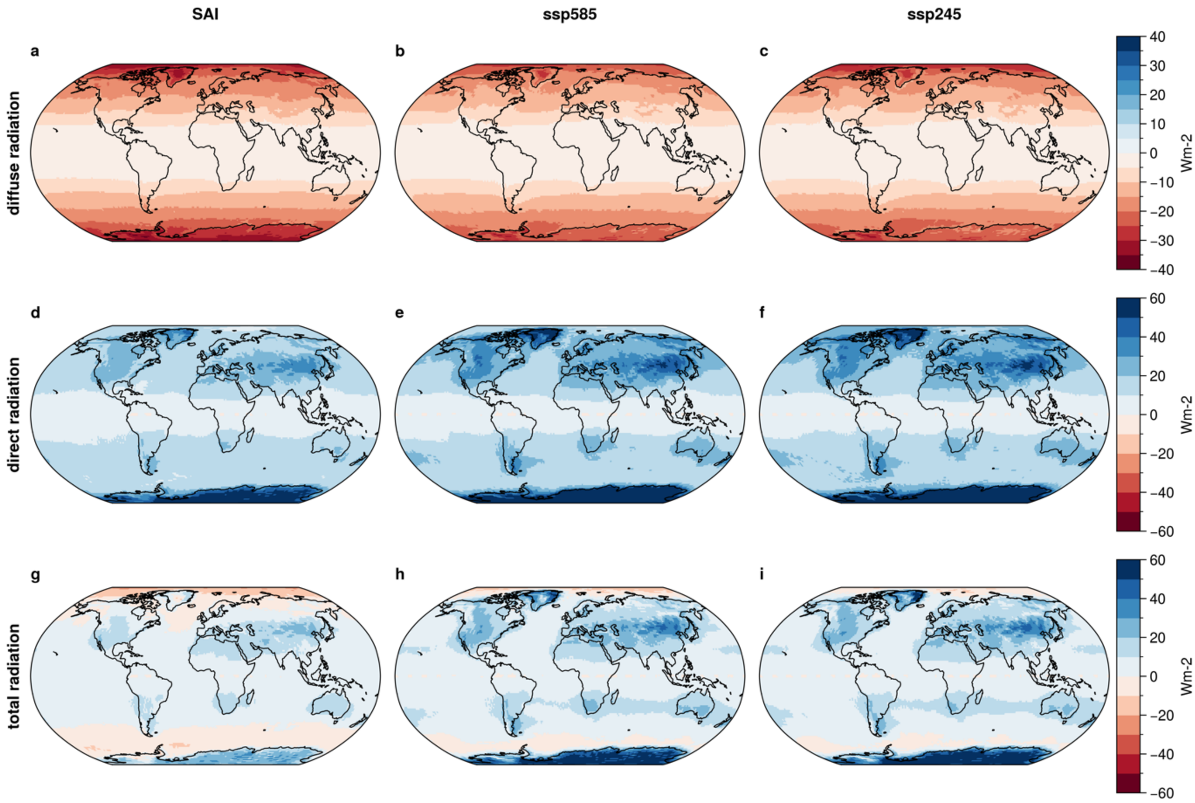

Figure 2: Difference in the direct and diffuse components of the PV potential calculation when solar geometry and panel tilt are accounted for (RSDSpanel) versus when radiation on a horizontally aligned panel is considered (RSDS). a-c) display the difference in diffuse radiation that is used in RSDSpanel versus in RSDS. d-f) same as a-c but for direct radiation. g-i) same as a-c but for total radiation.

2. Around line 272 there is a "quasi-linear" relationship for reduced potential. It looks fairly linear in time (fig. 6), but since we don't have the SAOD plot we don't know if it is linear in AOD. This would be quite a useful result to verify as if it is linear, it would be easy to transplant into an economic or integrated assessment model.

We agree and added the 10-year global mean AOD to Figure 7 (in the manuscript; Figure 3 in this response).

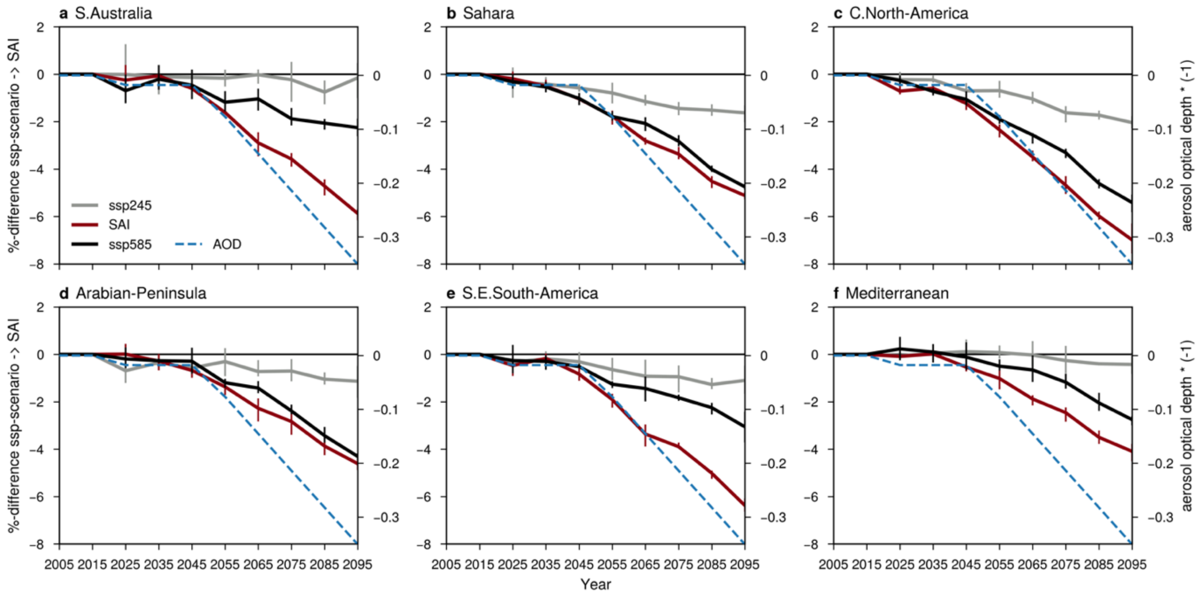

Figure 3: Relative difference over time of SAI (red), SSP245 (gray) and SSP585 (black) PV potential compared to 2015-2024 values for selected regions and global aerosol optical depth times -1 (blue) to compare change in PV potential with the magnitude of SAI deployment. Lines are the ensemble means with the bars indicating the 20-80 percentile ranges of the single members. X -> y denotes (y – x)/x.

"Figure 7 illustrates the temporal evolution of the relative difference between the three scenarios and present-day values with the increase in SAI deployment intensity over time. In the first four decades, the scenarios differ only slightly, but the gap in potential starts to widen as time goes on. The quasi-linear increase in the gap between SAI and the SSP-scenarios in some regions indicates that, in these areas, the reduction in PV potential strengthens with increasing global mean aerosol optical depth."

Minor points

Lines 35-37: several of the references are repeated

Done.

Line 73: "dystopian" I suppose is a slight value judgement

We removed it.

Line 86: A brief descripton of what G6sulfur aims to do, and the experiment design, would be useful.
Line 87: "imitates": I take from this that CNRM-ESM is not emissions driven for stratospheric aerosol injection. It is mentioned in the discussion, but would be good

to introduce here. Related to my comment about experiment design, what is the total loading or optical depth required to achieve the desired avoided warming?

We already give a brief description of what G6sulfur aims to do and refer to Ben Kravitz et al., 2015 for more information. However, we have included a sentence on the total aerosol optical depth (which is now also displayed in Figure 7 in the manuscript) and the fact that the scenarios are run in concentration-driven mode already in the Methods chapter. We also added more details on the difference between the existing CNRM-ESM2-1 G6sulfur simulations and the repetition of the simulations we have performed for this paper.

"We calculate the potential for three different scenarios: SSP245, a scenario representing approximate current policy (O'Neill et al., 2016), SSP585, a very high-emission scenario (O'Neill et al., 2016), and G6sulfur, an SRM scenario that imitates stratospheric aerosol injections (SAI) (Kravitz et al., 2015) and will be referred to as SAI in this study. G6sulfur has the initial conditions and underlying emissions of SSP585 but uses SAI to match the global radiative balance of SSP245 until 2100. G6sulfur is part of the GeoMIP protocol (Kravitz et al., 2015), but here, the setup is enhanced with higher frequency output and additional variables related to radiation and wind. We run the scenarios using the Earth System Model CNRM-ESM2-1 with prescribed aerosol optical depth derived from the GeoMIP experiment G4SSA (Tilmes et al., 2015) to simulate the aerosol injections in G6sulfur/SAI. 3-member ensembles of G6sulfur/SAI, SSP245 and SSP585 from CNRM-ESM2-1 exist already, but are not used here. Instead, for this study, we repeated the simulations with an alternative version of CNRM-ESM2-1 (Séférian et al., 2019) that accounts for the aerosol-light interaction. This additional feature of the model enables a change in the partition of direct and diffuse light due to a change in aerosol concentration in the whole atmospheric column. We run a 6-member ensemble with initial condition perturbations as for the standard SSP-simulations for all three scenarios in concentration-driven mode. The simulations cover the 2015-2100 period and output data is saved at hourly frequency. The global mean aerosol optical depth required in the SAI simulation to get from SSP585 to SSP245 reaches 0.35 in the last decade."

Line 92: "aerosol-light interaction", do you mean "aerosol-radiation interaction"?

Yes.

Equations 1 and 4: the LHS looks like a subtraction, would be better to be a subscript Tpi

Done.

Line 108 & 133: Format -2 superscript

Done.

Line 134, and a few other places – reference formatting a little sloppy and haphazard

We corrected the in-line reference formatting.

Line 157: is there a basis for choosing 500 km as the cut-off?

No, there isn't. We added:
"until it reaches a weight of 0 at a distance of about 500 km, an arbitrarily chosen cut-off."

Line 169: are low energy week boundaries fixed (i.e. Monday to Sunday), or do you take 7-day rolling averages?

The boundaries are fixed because a counting of weeks would not be possible with rolling sums. We included a sentence in the description of the LEW metric:

"The boundaries of the 7-day period are fixed."

Line 183: do the different population masks significantly affect the results? It feels like this isn't quite an apples to apples comparison.

Yes, different population masks affect which areas are considered suitable for solar farms and significantly affect the results (see for example S4d-f). For this to be as close to an apples-to-apples comparison we chose the same population setting for all scenarios.

Line 208: delete first "in"

Great, thanks.

Line 275: "a lot less well-behaved" – being a bit more explicit/formal here is useful.

We have included this sentence:

"The temporal evolutions are a lot less well-behaved with relative increases and decreases compared to the present that can be several times larger when the land-use suitability area weighting is included respective to its scenarios (Fig. S14) than when it is not (Fig. S13)."