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Interactive comment on "Trade-offs of Solar Geoengineering and Mitigation under Climate Targets" *by* Mohammad M. Khabbazan et al.

Anonymous Referee #1

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A review of the manuscript "Trade-offs of Solar Geoengineering and Mitigation under ClimateTargets" by Khabbazan et al.

The manuscript considers a joint strategy of emission reductions and SRM, where the use of SRM is constrained by regional precipitation 'guardrails'. These guardrails are hypothetical or illustrative, determined by scaling the regional mean precipitation observed in a 2C scenario without SRM. The authors then use an energy-economy-climate model MIND to calculate scenarios of such joint strategies.

General comments:

1. The overall concept of the paper is good. It provides some new (according to my knowledge) and concrete proposals for thinking about the negative impacts that SRM

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might have. Although the guardrails used in the scenarios are merely hypothetical, they illustrate the concept nicely.

2. On one hand, I really like that the climate impact is represented not only as the mean temperature change (which is certainly a proxy for many different things). But on the other, adding only precipitation as a more specific measure of climate change impact might be problematic. The authors should discuss this issue further.

3. My main concern is that the concept and modeling approach need to be presented much more clearly. When I started to read the results, I was unsure what the different cases were and how they were calculated. Section 2 focuses on describing verbosely why things are done in the chosen way, i.e. the underlying rationale; but is too vague on describing what is actually done. I provide some points in the specific comments, but the authors should aim more generally for a clear exposition of their approach.

4. The methods section describes the used methods (to some extent, see the comment above), but not the calculated cases. The definitions should also be covered under section 2 (rather than in the results, section 3). For example, how was the level and time profile of SRM determined? Was it uniform across the globe or was it determined somehow regionally? Did it start only in 2060, as Figure 4 suggests? These things are not stated anywhere, and it's hard to interpret the meaning of your results without such information.

5. Another main concern is that the results need to be presented in a better way. Now they are quite uninformative, and as a result, the paper misses it's potential. This requires substantial reworking of the figures and text. Please see the specific comments for some ideas.

6. Just a thought, but what might be interesting to see is the correspondence between the 'mitigation costs' (loss in economic growth) and some measure of additional precipitation that some chosen SRM or guardrail level entails. Another thing would be to understand which regions experience the SRM precipitation effects, and to which di-

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rection these effects are pointing (Figure 3 didn't provide this information, although it could have).

7. The manuscript would benefit from condensing the text, which is quite verbose at times. This would improve the clarity and readability of the text. A language check would also be a useful thing to do. I would also suggest using a colleague to check whether the paper is understandable for an outsider.

Specific comments:

P2, L5: You mention that 'any meaningful assessment must include a risk-risk trade-off'. However, there's no uncertainty or risk considered in your analysis, if I'm correct. So, does this mean that your analysis is not meaningful?

P2, L15: The statement on this paper being the first to use "an integrated analysis of SRM and mitigation in-line with the '2°C temperature targe" is inaccurate, as such analyses have been presented already earlier (e.g. Smith and Rasch, Climatic Change 2013; Ekholm and Korhonen, Climatic Change 2016; Emmerling and Tavoni ,Env. Res. Econ, 2018). There is also a review "Evaluating climate geoengineering proposals in the context of the Paris Agreement temperature goals" by Lawrence et al. (2018) that is related to this discussion. That is, the authors need to define this paper's novelty more carefully (which is discussed more in the next paragraph).

P3, L3: What does "admissible" mean here, as it can be interpreted in very different? The citation (Bruckner et al. 2008) is not very helpful here without a further explanation. Is there a better citation than a conference paper?

P3, L6: Somewhat unclear what is meant by "necessary condition" and "keeping the 2°C target in order" (retain?).

P3, L7: The question "How much regional precipitation change, as an example of a climatic change other than temperature, would someone, who has already accepted up to 2°C of global warming, accept?" is interesting, but too unclear to get what you

mean by it. Who is this 'someone', what means 'to accept 2°C' or 'to accept an amount of precipitation change'?

P3, L9: The next sentence ("If we were able to confine regional climate change. . .") needs also some clarification. Maybe break it into two or three sentences and explain the idea piece-by-piece? P3, L16-26: Please state more clearly and carefully whether you mean the average or the standard deviation of precipitation change in each context.

P3, L17: Why it's called a 'scaling coefficient'? I don't think this is used to scaling anything, but it represents the response in (average?) precipitation due to an increase in global mean temperature. Why it's a function with the second argument as 'CO2'? Should it rather be Delta T? (And, these maybe could be better expressed as indices, not function arguments.)

P3, L25: Please state more explicitly, that the extra admissible area is not based on any calculation of the impacts that the additional change in precipitation could bring about. That is, these are used only in an illustrative manner (which is perfectly ok, as long as it's stated clearly).

P3, L28: Introduce briefly what the Giorgi regions stand for or represent.

P4, L15-17: Here's a good example of a sentence that is too verbose and unclear. Please clarify.

P4, L24: Is "parabolic fit of the time evolution" a second-order polynomial trend?

P4, L29 onwards: Again, there is too much 'meta' talk about the model, but it's not clear what the model actually covers and models. What it means that the model "co-shaped the mitigation chapter of the Stern Report", and does it matter here? A comparison to "more advanced models" is not very useful, if I don't know how advanced or simple the MIND model is.

P5, L5: You extended the model, but how exactly? What regions it had earlier? A new regional split in this kind of a model is not a simple thing to do, so it requires some

further explanation.

P5, L12: Climate sensitivity seems not to be your focus in this work, so a shorter statement of this and the used value will do fine. Also, the defense for the simple climate module in MIND is perhaps a bit too long. Ok, it's simple and therefore inaccurate, but you perform sensitivity analysis to check this.

P5, L24-27: It is very hard to understand what the cases mean and how they have been calculated, as these weren't explained in the methods section. What does '2°C target activated' mean, or 'all regional constraints are binding'? How have the mitigation and SRM contributions been determined? This all is unclear for me.

P5, L30: So, the normalized values of 0 and 1 are not the max and min from the 'observations' between preindustrial and 2C scenario, but including the 5% or 10% leeway? Then, in the lower subfigures of Figure 3, the normalized levels 0 and 1 imply different absolute levels, am I correct? Please clarify.

P6, L10 onwards: This description is hard to follow. The panels c) and d) in figure 3 are too similar, and the measure (normalized precipitation change) too abstract to get much insights from it (please see also my comment regarding Fig. 3). I merely see (from Fig. 4) that the looser guardrail allows for a stronger level of SRM.

P7, L13: This is in one way a good idea, but quite off the point regarding the paper's topic. Additionally, the considered values seem rather arbitrary.

P9, L17-18: Wasn't the idea of guardrails exactly to manage risks of SRM, i.e. that the change in precipitation due to SRM will be small compared to that which occurs due to climate change itself. In this regard, it would be good to compare more explicitly the trade-off between mitigation cost and recipitation change (guardrail level).

P9, L25: I belief this is more of a 'feature' of your model, rather than a 'hard, cold truth'. I guess there's a plenty of scenarios that remain below 2C even with a higher climate sensitivity. You could perhaps just point out to the literature where SRM is discussed

from a ‘last resort’ perspective, if emission reductions are postponed too much, there’s tipping points or such.

P10, L6-8: I don’t think the final statements reflect your results. (Plus, the first sentence is rather vague.) I think SRM had a notable role in lowering the mitigation costs in your cases, whereas the precipitation change due to SRM was still confined into a quite moderate interval.

Figure 1: The figure would benefit from a few improvements, so that the main idea would come more clearly through to the reader. Please add degree Celsius symbol for the number two. Perhaps include some indication that the blue is some chosen fraction of the green (if I understood correctly). Is the y-axis the average of precipitation change? If so, this could be indicated there.

Figure 3: I don’t find the figure (when presented in this way) particularly informative. All it says that with BAU, climate change continues strong, with no restrictions on SRM the precipitation guardrails are breached in some regions (but not which), and with the guardrails in place – well, precipitation stays within the guardrails. The normalized results are too abstract to have much meaning for an outsider, while there is now information on which line is which region (I assumed they represent different regions, but this wasn’t said expressly in the caption).

Figure 5: This figure is quite confusing. There are too many acronyms. The caption says ‘mitigation costs’, but the y axis is ‘% of BAU BGE’. After some thinking I figured the connection between these, and how SRM with guardrails (case G0) lowers the mitigation costs (reduces the decrease in economic growth). But then, are the first two columns global figures; and which case the regional columns correspond to? Do only a handful of regions experience mitigation costs? Is mitigation virtaully free in e.g. North America and Europe? This confuses me a lot. (Additionally: why TradCEA was not listed as one of the calculated cases?)

Figures 3, 4 and 5: Maybe include more informative titles for the subfigures than the

‘codes’ (BAU, REF etc.)?

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