

To: Peter Haynes, Editor, ACP

Subject: Revision of Manuscript Reference Number eguspher-2022-974

Prof. Peter Haynes,

Upon your recommendation, we have carefully revised the manuscript after addressing the comments and suggestions made by the reviewers. All the changes made in the manuscript are tracked in the pdf-file named “Manuscript_Highlighted_Changes”. The following is also the point–point response to all the comments (the comments are rewritten in black color and their corresponding replies in red). We appreciate the opportunity to revise my paper.

Notice: The line numbers refer to those in the marked version of the manuscript named “Manuscript_Highlighted_Changes”.

Response to the editor:

Public justification (visible to the public if the article is accepted and published): The two referees who provided reports on the first version of your paper have kindly provided further reports on the revised version. Both state that the paper is significantly improved, however both request further revision before the paper is suitable for publication. Please can you consider the new reports carefully and provide a revised version of the paper and clear responses to the referees' comments. (I note that both referees request improvement to the quality of the figures.)

I believe that the revisions recommended are relatively straightforward and if you deal thoroughly and clearly with these further referee comments then my hope is to be able to accept the paper at the next stage without further consultation with the referees.

Reply: We sincerely appreciate your effort and time in handling our manuscript. In the previous version, we previously uploaded a version with much reduced quality figures and small-size pdf-files for speed. However, we have now uploaded a manuscript containing the figures in their original high-quality format.

Response to RC1:

Thank you for the revisions. I still have some issues with the interpretation of the results as described below. I would recommend making the figures higher resolution to facilitate

understanding.

Reply: We sincerely appreciate your approval of our revision. We have attempted to revise the manuscript in light of your new suggestions/comments. The following is also the point–point response to all the comments (comments are rewritten in black color and their corresponding replies in red).

Major comments:

- “Although the SAI is mostly accompanied by a slight decrease in the median of El Niño/La Niña characteristics towards their historical value, its effect on global warming imposed-changes is only statistically significant for the intensity and duration of La Niña events.” This is only true for CESM2 as far as I can see.

Reply: We have added the word “For CESM2,” to the sentence (please see line 343).

- The fact that fig. 8a shows near-zero power for AMO in the SAI case for periods greater than 50 years seems odd. Do we have an explanation why that is? Could it be due to a mistake?

Reply: This is the result. The AMO time series from all the scenarios have been obtained using the same code.

- “The decadal 10-20-years mode of the historical NAO is not preserved in the global warming scenario nor with SAI (Fig. 8b).” The difference between the green and blue/red lines of figure 8b do not seem that large. Can you zoom in on the relevant part of the figure?

Reply: We have replotted the NAO graph on a log scale, and now has higher resolution (please see new Fig. 8).

- For NAO and ENSO, all the information is scrunched up to the left of the figure. Maybe use a log scale, that could make it easier to see the information.

Reply: Implemented (please see new Fig. 8).

Minor comments:

- L.334 typo La Nino

Reply: Implemented.

- L.356 typo S5

Reply: Implemented.

Response to RC2:

Thank you for the revisions. I still have some issues with the interpretation of the results as described below. I would recommend making the figures higher resolution to facilitate understanding.

Reply: We sincerely appreciate your approval for our revision as well as constructive comments/suggestions. We have attempted to revise the manuscript in the light of your new suggestions/comments. The following is also the point–point response to all the comments (comments are rewritten in black color and their corresponding replies in red).

This updated version of the study is much improved on the initial draft, with many of my concerns addressed with detailed changes. However, I would still suggest several minor revisions. In particular, I think the paper would still benefit significantly from edits to the figures to improve the visual quality, including the resolution, font size, choice of annotated text, and choice of colormaps. See detailed comments below:

Reply: We previously uploaded a version with much reduced quality figures and small-size pdf-files for speed. However, we have now uploaded a manuscript containing the figures in their original high-quality format. We further edited the figures mostly based on your new suggestions.

Lines 523-525: “The decadal and inter-decadal variability modes of all the historical climate indices (except for Atlantic-based indices under SSP5-8.5) are not preserved in the GHG warming scenario and the SAI does not restore them.” I find it difficult to

understand exactly which changes are referred to here, I suggest listing specifically which modes of variability are not restored, and where the reader can see this from the figures.

Reply: We have added the mode-years (please see lines 552-553). In the conclusions, we do not usually refer to figures.

Line 527 “AMO and no effective impact” should read “AMO and have no effective impact”

Reply: Implemented (please see line 557).

Lines 450-465: This description of some of the theoretical background to changes in the modes of studied, is very useful. However, I think the section could benefit from explicitly stating how SAI would be expected to change the patterns of variability studied under this theoretical framework.

Reply: Agreed, good point. We have added 2 paragraphs of discussion in this section (please see lines 471-479 and 489-500):

The impact of SAI on the energetics of the coupled system are to offset the GHG increases by design. Hence, we might expect that SAI could therefore reduce or stop the progression towards chaotic behavior. However, the real climate system is far more complex than a simple energy balance calculation. SAI increases stratospheric heating (Visioni et al., 2020), and this leads to tropospheric changes, especially in winds (Gertler et al., 2020), and tropical circulation (Cheng et al., 2022). Furthermore, the large heat reservoir of the global ocean has been out of equilibrium with the atmosphere for centuries of anthropogenic GHG emissions, and this excess heat cannot be dissipated by SAI within the timeframe in the simulations. So, we may expect SAI to, at best, imperfectly reverse the effects of GHG on teleconnections.

While SAI effectively reverses the changes in the spatial patterns under GHG forcing across the North Atlantic (i.e., AMO) and North Pacific (i.e., PDO) and compensates for modest changes in the characteristics of the El Niño and La Niña episodes (related to the tropical Pacific), it does not effectively suppress the projected changes in decadal (~10-20-year) and inter-decadal (longer than ~20-year) variability of circulations imposed by global warming. Anthropogenic aerosols intensify the interannual variability (particularly in ENSO) but weaken the longer than 10-year signals of the ocean-

atmosphere circulations, compatible with the multiyear to decadal variations in PDO (Hua et al., 2018). SAI involves aerosols in the stratosphere not the troposphere, so the effects will be different, not least because of stratospheric heating (Visioni et al., 2020). The cold-tong patterns in the mid-latitude of both North Atlantic and North Pacific tend to have an excess eastward extension under SAI, in line with the second-phase of the North Pacific response to large volcanic eruptions (Wang et al., 2012), which are better analogues for SAI.

Ref:

- Cheng, W., MacMartin, D. G., Kravitz, B., Visioni, D., Bednarz, E. M., Xu, Y., ... & Deng, X. (2022). Changes in Hadley circulation and intertropical convergence zone under strategic stratospheric aerosol geoengineering. *npj Climate and Atmospheric Science*, 5(1), 32.
- Gertler, C. G., O'Gorman, P. A., Kravitz, B., Moore, J. C., Phipps, S. J., & Watanabe, S. (2020). Weakening of the extratropical storm tracks in solar geoengineering scenarios. *Geophysical Research Letters*, 47(11), e2020GL087348.
- Hua, W., Dai, A., & Qin, M. (2018). Contributions of internal variability and external forcing to the recent Pacific decadal variations. *Geophysical Research Letters*, 45(14), 7084-7092.
- Visioni, D., MacMartin, D. G., Kravitz, B., Lee, W., Simpson, I. R., & Richter, J. H. (2020). Reduced poleward transport due to stratospheric heating under stratospheric aerosols geoengineering. *Geophysical Research Letters*, 47(17), e2020GL089470.

Figure 1 has text of very small font size on the axis labels, titles running into data, and most importantly, the data itself is too small to comfortably compare the index variation between scenarios. The y-axis labels have unneeded square brackets following the label. Panels g-l are missing 'NAO' from the label.

Reply: We previously uploaded a version with much reduced quality figures and small-size pdf-files for speed. However, we have now uploaded a manuscript containing the figures in their original high-quality format in which the texts and labels are now clear. The square brackets on y-axis have been removed. We also added the 'NAO' to the labels.

Figure 2: authors might consider increasing the size of this figure by making it a 3x2 grid (three rows of 2 subplots). The p-values annotated on the figure are quite confusing, because the position nearly aligns with the x-axis position of the bars. I initially thought

each value referred to one bar and so struggled to understand what they represented. I suggest rearranging somehow to avoid this (e.g., perhaps list vertically rather than horizontally?), or perhaps moving these values to a table. I would also suggest that the precise values here are not necessary, and e.g., <0.01 , $<10^{-5}$ etc. could be used instead. Finally, I wonder if the blue text with date ranges could be better placed in the x-axis tick labels.

Reply: We have uploaded the figure in the original high-quality format in the new version. In the figure caption, we explained about the annotated p-values and blue text and believe that they are clear. For the p-values, we have shown only two-digit values in the new figures (please see new Figs. 2 and 7). We have tested different arrangements for subplots, the current format is the best.

Figures 3-6: The authors might consider using a colormap with white at center to allow better distinguishing of positive and negative anomalies.

Reply: Implemented (please see new figures 3-6).

Figure 7: similarly to Figure 2, I suggest the authors might consider making this figure larger, with 4 rows of 3 subplots to improve readability.

Reply: We have tested different arrangements for subplots, the current format is the best.

Line 236: it would be clearer to split these equations across two lines, as the comma is easy to miss

Reply: We have replaced comma by “where” to avoid this (please see line 234).