

Reviewer's comments are in bold. Authors' responses are in blue.

Review of "Potential limitations of using a modal aerosol approach for sulfate geoengineering applications in climate models" by Daniele Vioni et al. submitted to ACP, <https://doi.org/10.5194/acp-2021-678>

Overview: This study examines how well a modal aerosol model represents tropospheric aerosol loadings in a stratospheric sulfate geoengineering model. The authors demonstrate that the internal mixing assumption of the modal model degrades the simulation of upper tropospheric ice clouds. The overall conclusion is that care needs to be taken when simulating the evolution of stratospheric aerosols with a modal model where the resultant aerosols probably are not internally mixed in actuality. Cases noted are stratospheric geoengineering as in the GLENS runs, and possibly when simulating large volcanic eruptions. The authors also note that this could be an issue in modeling a geoengineering scenario consisting of cirrus cloud thinning in conjunction with increasing stratospheric aerosols via SO₂ injection. Overall, it's an interesting paper requiring minimal revision, but requires very careful reading to understand all the points that are important. Figure 1 needs to be revised (see comments below) and I suggest the authors make sure the figure captions fully explain what is shown in the multi panel figures.

We thank the reviewer for their supportive comments and insightful suggestions for improvements. We address the specific comments below.

Specific comments:

1) (Minor) Crutzen (2006) is not the first study to suggest stratospheric aerosol enhancement to counter global warming. NAS (1992), Panel on Policy Implications of Greenhouse Warming, Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base. Washington, DC: Natl. Acad. Press could be referenced, or even one could go back to the original work by Budyko (Budyko, M. I. (1969). The effect of solar radiation variations on the climate of the Earth. Tellus, 21(5), 611–619. <https://doi.org/10.1111/j.2153-3490.1969.tb00466.x>)

Thank you for the suggestion, we have added the reference to the study from Budyko.

2) Line 105-114: The short description of the GLENS runs is not entirely clear, and there seems to be differences between the project documentation page (<https://www.cesm.ucar.edu/projects/community-projects/GLENS/>) and what is detailed here. The project page says 20 member ensembles, while this says 21. Make it clear that the 2010-2030 runs are the control runs with no geoengineering. Also, the project page says that 3 members without SAI go to 2100, while this text says 4. It may be that the description here is correct, and the project web page is wrong, but the project web page agrees with the Tilmes et al., 2018a reference.

Thank you, we have tried to make the description clearer. The reviewer is right that the documentation page only mentions 20 ensemble members, but after Tilmes et al. 2018 one further ensemble member was ran, due to the need to include some more variables unavailable on the original runs for a project unrelated to this paper, and we also included that run here. We have tried to specify this now, and will work to update the documentation page too.

3) Figure 1: The caption refers to a black box indicating an area, and then green boxes are mentioned. I can't tell what is meant there, because I don't see a black box, but rather a black hat shape almost (at 110 hPa, lines from 90S-60S, and 90N-60N, and then at 60 hPa from 30S to 30N). And, there are 3 green boxes. So, perhaps instead you can say in the caption what the area of consideration is, does black box mean everything under the black line, or everything above it? And, the letters (a,b,c,d) are on the figures, but no described in the caption (just delete them). The bottom left and center figures have text that overlaps. The caption should also say what the blue and red lines are. (they are labeled in the figure as baseline and GLENS for the middle panels, the caption should say that too, and also if that is valid for the rightmost panel). Defining the Baseline case in the caption would be useful as well. Also, define in the caption what is meant by "last 20 years" for the rightmost panels. Is that 2100-2080 in the simulation? And is red RCP8.5 (no SAI) and Blue RCP8.5+SAI? And what mode it is should be labeled on each panel (rather than calling things SO4a etc). The figure labeling is a little confusing.

We thank the reviewer for their suggestions, and we apologize for the confusion! We have tried to improve the figure now and made the caption clearer. The new caption reads:

"Mass concentration (in $\mu\text{g per kg of air}$) of Coarse mode species (Sulfate (SO₄), Dust (D) and Sea Salt (SS), from top to bottom). On the left, panels a) indicate the Baseline (2020-2029) zonal mean concentration for the respective species, with the black and green boxes indicating the area considered in the averages for the central panels (panels b and c). The uppermost limit of the green boxes and the lowermost limit of the black boxes coincide. Panels b) and c) for each species show the annual evolution of the concentration in the black (panels b) and green (panels c) boxes, with lighter lines showing the single ensemble realizations, and the thicker lines show the ensemble mean; red lines indicate the Baseline simulations, while blue lines indicate the GLENS simulations. On the right, panels c) show the vertical profiles in both cases (Baseline, in red, and GLENS, in blue) for the period 2080-2099. Black dashed lines in the c) and d) panels indicate the periods of analyses for the a) and d) panels, respectively; the same lines in the d) panels indicate the altitude of analyses in the b) and c) panels."

4) Line 218/219 says "However, the vertical profiles of tropical concentration for the three species seem to exclude that." This isn't shown in figure 1, should this include a reference to figure 3?

It does show that in both Figure 1 (panels d) and Figure 3. We have updated the phrase to better reflect that.

5) Figure 4: what do the dashed lines in the panels mean? I've assumed in the top 2 panels that tells what is being plotted in the panels below. But I've no clue what the line at ~400 hPa means.

We assume the reviewer is talking about Fig. 5 as there are no dashed lines in Fig. 4 at 400 hPa. We have removed the lines since they belonged to another piece of analyses we then didn't use. Thanks for pointing it out.