

## **Review of Hirasawa et al., G6-1.5K-MCB: Marine Cloud Brightening Scenario design for the Geoengineering Model Intercomparison Project (GeoMIP) in CESM2.1, E3SMv2.0, and UKESM1.1**

This article's aim is to provide the protocol for the submission of a mid-latitude marine cloud brightening experiment within the GeoMIP project. The target intervention simulation consists in sea salt aerosol injections in the lower boundary layer of 5 midlatitude oceanic regions, with programmatic emission adjustments to keep 21<sup>st</sup> century global mean surface temperatures within  $+1.5\pm 0.2\text{K}$  compared to pre-industrial levels against a SSP2-4.5 scenario background. The required set of simulation also includes two benchmarking simulations aimed at adapting the emissions to each model's radiative sensitivity to sea salt perturbations. The requested output variables are described. The protocol is demonstrated with three test earth system models, CESM2.1, E3SMv2.0, and UKESM1.1. Results with these 3 models show that midlatitude MCB effectively counteracts SSP2-4.5 annual warming with minimal anomalies in surface temperature and precipitation, despite some differences in intra- and inter-model regional and seasonal responses. This article is clear and well-written, and I recommend accepting it after minor reviews.

### **General comments:**

- The introduction could benefit from an earlier description of the past and present GeoMIP aerosol experiments, and how the proposed experiments complement the already existing ones: many mentions of G6-1.5K-SAI are already made, but the past G4seasalt MCB experiment is only mentioned briefly on Ln 115, while the mention of the G4cdnc experiment only comes in the conclusion. A sentence about the scope and aim of GeoMIP at the beginning of the introduction could also be informative.
- Mid-latitude sea salt injections seem to work better than tropical injections without adverse side effects. At least in the three models studied here and in H2025, but this is limited evidence. How confident are you that other models would reproduce the same behavior?
- On Ln 360, it is said that "these simulations are not suitable for estimating the iSSA mass or number emission required for actual deployment but are instead aimed at identifying and understanding the sources of inter-model differences in cloud and climate response to MCB". In my opinion this is a critical point, and even though this is re-iterated on Ln 532 and 550, I think the aims of this GeoMIP project should be addressed more clearly early in the introduction: 1) evaluate climate impacts of midlatitude MCB as a geoengineering approach, while 2) assessing inter-model variability in interactions between sea-salt aerosols and clouds, but 3) not providing any guidelines for actual deployment due to these uncertainties.

### Specific comments:

- Ln 12: suggestion to add the following precision for clarity: “maintain 21<sup>st</sup> century GMST at 2020-2039 temperatures”
- Ln 30: “among other considerations” sounds purposely vague, I would remove
- Ln 35:
  - o Cite the Twomey effect paper
  - o You should also explain that there are cloud adjustments, especially since you mention the cloud lifetime effect several times in the article.
- Ln 38/39: References missing here. Which “evidence”/“studies”?
- Ln 39: “it’s its”
- Ln 54/55: I would include the spatial extents of the 5 regions here, instead of having this information in the caption of Fig.1.
- Ln 56: You could describe the mechanism behind the “stronger positive radiative feedbacks”
- Ln 116: Why is the degree of comparison between studies and models “limited”?
- Ln 126: Calling this MCP scenario a “deployment scenario” somehow contradicts the later statement (Ln 360) that this initiative should not be considered informative about actual deployment.
- Ln 144: missing word “based [...] the”
- Ln 148: I don’t think the NH and SH have been defined before
- Ln 160-163: This sentence is unclear to me, maybe consider rephrasing
- Ln 162: Did you mean “computeD”?
- Ln 189: It’s not clear to me which portions of the SH are not covered?
- Ln 190: I assume the emission is uniform in all of the gridboxes inside of each region, but maybe it’s worth specifying.
- Ln 283: Parentheses missing around the citation
- Ln 293: It sounds like only UKESM1.1 represents the cloud albedo effect, but I think all 3 models do here. As per my previous comment, “cloud lifetime effect” hasn’t been defined before (nor “cloud albedo”, even though I assume you use it as a synonym for the Twomey effect)
- Ln 314: I’m not sure what the “initial analysis” refers to. Fig. 1 to 8? Or previous analyses in H2025? Or Stage 1 and 2 simulations only?
- Ln 315: I don’t understand why some simulations have balanced hemispheric emissions, in disagreement with the proposed protocol. If it’s just because you’ve improved the protocol since the first simulations have been run and you don’t want to re-run them for computation resources reasons, I think it’s ok to say so

- Ln 316: For Fig.1, It bothers me to have “TOA Global Average” or “cloud”, “non-cloud” as labels. I would use less ambiguous y-axis and colorscale labels, for instance: Global ERF (bottom row) ERF\_direct (middle) , ERF\_aerosol-cloud (top).
- Ln 356: Fig. 2
  - o could you add in the y-axis labels that the plotted variables are *anomalies*? And specify in the caption what is the baseline for computing these anomalies? I assume it's with respect to the 2020-2039 average in the SSP2-4.5 scenario. Same comment for Fig. 3.
  - o Note that using red and green is not colorblind-friendly
- Ln 370: Does the fact that the cloud lifetime effect could modulate the Twomey effect also contribute to the non-linearity?
- Ln 388: What does a “hydrologic increase vs. decrease” mean?
- Ln 393: is there a missing “no” here: “show [...] change”? Because the tendencies look rather undistinguishable from the constant line in Fig. 3d-f
- Ln 403: Is there a missing preposition here? “flux [...] equator”
- Ln 410: did you mean southward for CESM2.1 and northward for E3SMv2 ? In which case it does not oppose the SSP2-4.5 scenario effect
- Ln 453: The cooling pattern does not oppose the SSP2-4.5 warming pattern at high latitudes though, does it?
- Ln 462-466: Maybe the hatching in the precipitation plots is too coarse, or I'm not looking at the right place, but I don't see the pointed out regions as having significant changes (Central Africa for E3SM, or the increases in the subtropical regions). Same comment for the seasonal maps described Ln 467-473,. For example, I see significant changes over Central Africa in JJA for UKESM, but not the changes described on line 473.
- Ln 492: Could you remind the reader what the references for the recent ESM studies mentioned here are?
- Ln 498: “comparison of the intervention strategies” – here, do you suggest that this protocol's simulations could be compared to previous simulations from other GeoMIP projects such as G4seasalt and G4cdnc?
- Ln 509: whether the differences are “subtle” between cloud droplet number and aerosol perturbations could be questioned. I would remove the adverb.
- Ln 516: “with the majority of the forcing occurring via aerosol-cloud interactions”: that is only true in 2 models out of 3. To come back to my general comment about generalization to more models, do you think you can make a general statement like this before other models are added to the comparison?
- Ln 519: You could be more specific than “substantially lower” (20 and 2.5 times lower, resp.)