

A New Era for the Geoengineering Model Intercomparison Project (GeoMIP)

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What: Geoengineering Model Intercomparison Project (GeoMIP) held its thirteenth annual meeting, together with an early career workshop, with over 100 registered participants to discuss results of previous GeoMIP simulations and plans for future experiments to run as part of the new set of CMIP simulations.

When: 3–7 July 2023

Where: Exeter, United Kingdom

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The thirteenth GeoMIP meeting was held in Exeter, United Kingdom, 5–6 July 2023. It was complemented by an early career meeting (ECM) that was held before (3–4 July) and after (7 July) the GeoMIP meeting. It was the largest GeoMIP meeting to date, with over 100 registered participants and over 70 joining in person in Exeter (see the group photo in Fig. 1); the ECM hosted over 30 graduate students and postdocs. Both saw a large participation of scientists from the Global South thanks to funding from the Developing country Governance Research and Evaluation for SRM (DEGREES) initiative and the U.S. National Science Foundation.

The ECM was devised to introduce first-time GeoMIP attendees to the science that would be discussed during the meeting, and to allow younger researchers to get to know each other and to share their research in a lower-pressure environment. It started with a series of talks that summarized the history of solar radiation modification studies, from the early proposal by Mikhail Budyko to the history and motivations behind GeoMIP itself, followed by an overview of how currently the Climate Model Intercomparison Project (CMIP) and the Intergovernmental Panel for Climate Change (IPCC) think about future climate projections and scenarios. Then one of the main authors offered an overview of the recent chapter of the *Scientific Assessment of Ozone Depletion: 2022* that deals with stratospheric aerosol intervention (SAI). This was followed by talks and poster presentations by the ECM participants, who shared their research with their peers and received useful feedback. In the afternoon of both days of the ECM, time was reserved for the participants to split into groups and discuss between themselves what they would be expecting from the GeoMIP meeting, with the aim of discussing on Friday whether their expectations had been met or not. During the second day of the workshop, lectures aimed at discussing initiatives and perspectives related to the governance aspect of SRM were held after lunch, with a focus on the involvement of the Global South in the conversation.

The thirteenth meeting started on Wednesday with an overview presentation by both cochairs, highlighting some of the main topics to be discussed at the meeting. These mainly involved the current role of GeoMIP and how future sets of experiments would consider and include future plans laid out at the ScenarioMIP meeting held two weeks before in Reading (van Vuuren et al. 2023) for the next set of scenarios that would constitute the bulk of the next phase of CMIP. Aided by the talks by the various members of the community, the cochairs highlighted the necessity to make concrete decisions about an “intermediate” experiment to be run with the current set of ESMs and current scenarios, and potentially to be replicated with a future set of experiments with the next generation of ESMs, the next generation of ScenarioMIP scenarios, or both.

The rest of the day was filled with talks and poster sessions and a hybrid meeting of the Geoengineering Modeling Research Consortium (GMRC; www.cgd.ucar.edu/projects/gmrc).



Fig. 1. Photo of all meeting participants taken outside the meeting venue at Exeter University.

The morning GeoMIP talks provided an overview of state-of-the-art research capable of informing the next sets of experiments, and involved discussions over the technical “feasibility” of previous experiments, potential new methods to devise scenarios relying much more on idealized experiments and on emulators, and some initial proposals for the next experiments, including both SAI and marine cloud brightening (MCB). The afternoon talks highlighted current or proposed experiments that focus more on exploring and resolving single modeling uncertainties, such as stratospheric ozone changes using a common set of prescribed aerosol properties, and dynamical impacts of stratospheric heating. On Thursday, the morning included eight talks that mostly focused on using current experiments to assess various impacts, to highlight the needs of the impact assessment community in the context of GeoMIP. In the afternoon, a 2-h discussion concluded the meeting. The discussion was very lively and touched on many fundamental points that will, in many ways, decide the future of GeoMIP.

GeoMIP governance

The GeoMIP community is, by all accounts, growing. This was a rather large meeting by the standards of the previous 12; a variety of geographical locations were represented, and so were the variety of expertise and interests. The usual core group of climate modelers, while always present, was complemented by many more researchers interested in understanding numerous climate and ecological related impacts, both at global and local scales, and by researchers working on laboratory studies interested in integrating and validating their work within climate models. This was complemented by researchers in the social and political sciences, as well as engineers. This progression from the core group to a more diverse group is a natural evolution reflecting that GeoMIP provides a unique platform to share broader results around the topic, even if not directly connected to GeoMIP. Many agreed that future meetings should remain likewise welcoming. Nonetheless, the community generally agreed that, given the need to build legitimacy around SRM research, we should avoid accepting applications from individuals who are not aligned with that mission. Future meetings should have a clearer set of rules over criteria for abstract and participation acceptance.

A new intermediate experiment

The discussion quickly converged around the issue of a new experiment to be proposed. A document outlining the discussion at length, and the potential proposed experiment is in

the works and will be separately sent to interested members of the community, and shared through a discussion paper in the journal *Geophysical Model Development* for comments from the community (Visioni et al. 2023c). It was clear from the discussion and from further feedback received by the cochairs that new and more open ways to design future experiments need to be devised. As both documents will be open for public discussion, there should be plenty of time to obtain more feedback on the current proposal, and on the overall structure of future decisions.

The road toward CMIP7

A longer-term plan for the set of experiments to be conducted as part of the seventh CMIP iteration (CMIP7) was also discussed. While final decisions do not need to be adopted until the next meeting, it was useful to share reflections within the community as a preparatory step, to have a more concrete base for 2024. A few themes were highlighted, in line with what was discussed in the recent GeoMIP review published in *Atmospheric Chemistry and Physics* (Visioni et al. 2023a):

- 1) *A set of idealized experiments capable of informing the development of emulators.* Considering the multidimensionality of the problem, there are constraints to how many different scenarios in fully coupled simulations can be proposed. As one talk on Wednesday highlighted, experiments like G1 or G2 can be used to build emulators capable of exploring the space of potentially different deployments from a different perspective. Which experiments are most useful for this purpose remains to be seen, and it will be an interesting area to explore in the next 12 months. For instance, replicating an experiment like G2 (with an underlying 1% per year CO₂ increase scenario; Kravitz et al. 2011) could be useful to inform the response that an emulator aims to replicate. If it makes sense to run a G1sulfur or G2sulfur (with similar aims as G1 and G2, and similar injection strategies as the new experiment proposed for SAI) or for MCB experiment is one of the sets of decisions worth considering.
- 2) *Single forcing experiments.* For both SAI and MCB, there might be the need to consider “simpler” experiments that only include either injections at specified locations for SAI (as in Visoni et al. 2023b), or considering only the most susceptible areas for MCB [as in Haywood et al. (2023) and others] in order to inform more complex experiments (i.e., with multiple injection locations, or a dynamic evolution of multiple areas targeted by MCB). These experiments do not need to be long, but have been demonstrated to be very relevant for the development of more complex strategies, and for understanding the additivity of multiple local forcings (Hirasawa et al. 2023). For MCB, the point was raised that, given current challenges around cloud responses, to have more models involved, a simpler form of forcing, not targeting clouds explicitly but rather the top-of-the-atmosphere forcing, should be considered, as was done in G1ocean-albedo.
- 3) *ScenarioMIP-adjacent scenario.* Just as for the discussion around the intermediate experiment, the opportunity to continue having an experiment in CMIP7 that follows ScenarioMIP protocols has been highlighted. Decisions cannot be made before the new set of scenarios is proposed, but the discussions around the intermediate experiment, and the need for a resilient protocol that allows for comparisons across model versions, should be taken into account. It is extremely likely that new CMIP7 scenarios will be emissions driven rather than concentration driven, posing some challenges in the development of the scenarios for GeoMIP if the target is, as in CMIP6, a high and a medium tier forcing. This push for a “politically relevant” scenario should not mean that GeoMIP has to run scenarios that at all costs need to pass a certain threshold of “political credibility,”

however subjectively defined. The main point of GeoMIP still remains finding common ground, and simple protocols, to make sure results from different climate models are actually comparable in order to understand models' uncertainties. In this context, not every scenario needs to be run in a multimodel framework, and especially ones that have not been tested before. Nevertheless, interested modeling centers could *also* run some of those less "idealized" scenarios to compare against the simpler ones run by the whole group in order to compare the two.

Data needs

Multiple scientists, especially from the Global South, highlighted the need to be able to obtain more data from the current sets of GeoMIP simulations (i.e., submonthly, variables not currently available). These issues were particularly noted by those researchers involved with modeling hydrological extremes where daily data are required to couple to hydrological models such as the SWAT model that is commonly used for extreme river flow and flood analyses (e.g., Tan et al. 2020). The data supply and storage issue is complex and involves all of the CMIP process, where modeling centers have limited capacity and might find it hard to fulfill the communities needs. For future experiments, a "core" set of variables that many would find useful should be defined for impact assessment purposes. There will be an effort by the cochairs to reach out to interested groups in order to better define what this core set should be: at the same time, this highlights needs for data storage and data sharing that should be raised with funders and funding agencies to make sure that the produced data are actually useful to the community.

Future meetings

There was strong agreement for future plans regarding the next two meetings to be held. The fourteenth GeoMIP workshop will be at Cornell University in Ithaca, New York, in the summer of 2024 and the fifteenth will be at a yet-to-be-determined location in Africa in 2025, giving us time to secure funding, settle on a location, and organize the first SRM meeting to be held in Africa.

An online meeting point for the GeoMIP community

Many early-career scientists also highlighted the possibility of having a way to increase GeoMIP presence online through a platform like GitHub. While the website is a great repository, it lacked a discussion forum for advice and questions and a place to share code. This place now exists (<https://github.com/GeoMIP>) and will be used in conjunction with the mailing list and the website to keep the GeoMIP community informed. Volunteers among the early-career scientists will ensure the GitHub project is kept up to date.

Conclusions

The workshop ended on Friday with the last day reserved for early-career scientists, with the aim of listening to their feedback on the meeting over the prior two days. Every early-career scientist was given the opportunity to share their opinion, which allowed the cochairs to collect an interesting list of potential future improvements to consider. Lots of focus was given to the ways in which the Thursday discussion went, highlighting that it was mainly led by those most experienced and with more knowledge about the process, and that the choice of the future GeoMIP experiments felt, to many participants, to be a foregone conclusion. Many pointed out that a longer and less constrained meeting, with more time for discussion not just in plenary but also in smaller groups, would be conducive to more voices being heard, and this is certainly something that will be taken into account for future meetings. The feedback

also highlighted the need to increase the amount of preparatory work before the beginning of the meeting, which might include suggestions on recommended readings and a poll to gauge people's thoughts and ideas beforehand.

Overall, while many seemed to be satisfied with how the meeting went, there was also a general agreement over the need for rethinking some of the current ways in which the GeoMIP meeting is structured and organized to ensure broader participation in the process. Thus, the GeoMIP process evolves and will likely continue to be the largest international project conducting climate intervention research.

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