Cornell Climate Engineering Group - what happened in 2023

To say that 2023 has been an exciting year for the Climate Engineering group at Cornell would be an understatement!

Firstly, January started with Doug in the role of Senior Researcher and Dan in the role of Research Associate, and is ending with both of them in the role of Professor (Associate and Assistant, respectively). This brings a much needed sense of stability for the group and for the many projects we have in mind, and is the culmination of a lot of groundwork with Cornell and the Atkinson Center with the aim to create organic, bottom-up support for SRM research within such a large institution. The good news is: it worked. Two Colleges (Engineering and CALS) have realized how important it is to invest resources in this field, and the support from the departments involved has been unanimous, opening up avenues for future collaborations. Plans for the new years involve leveraging the new positions to expand the group, by recruiting more graduate students both with Atmospheric Science and Engineering backgrounds, and by hiring more postdoctoral researchers to carry out new groundbreaking research and support the activities of the group.

Our 2023 research

Speaking of groundbreaking research, this has also been an incredibly positive year for that. The new scenario framework developed in the last two years, and published in 2022 in PNAS, has gathered lots of attention and is starting to bear fruits, with many examples of novel research involving potential SAI impacts being published or underway not just at Cornell, but worldwide. The framework (**Figure 1**) has allowed researchers interested in understanding the impacts of SAI to find out in their research how much the answers to “What would SAI do to *X*” depend on being clear about the goals of the SAI strategy: how much you’re cooling, what period you’re comparing against, where are you injecting, when, what is happening in the meantime?

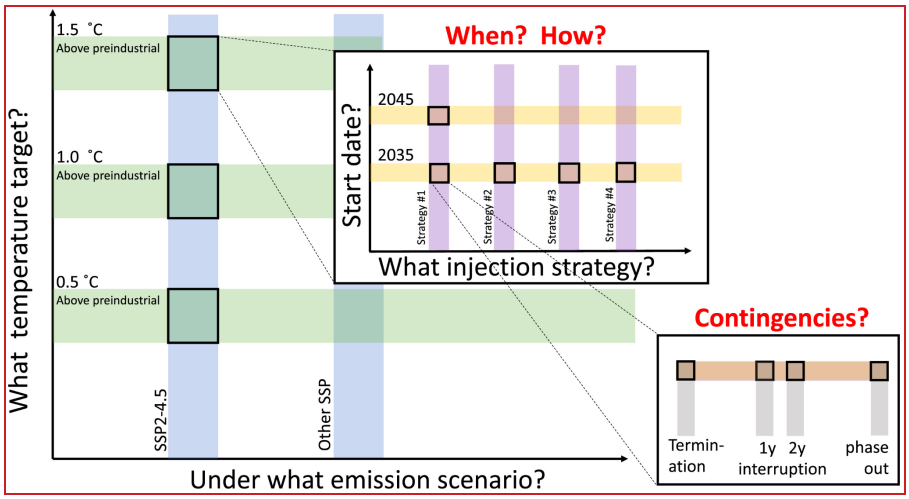

Figure 1 *Our scenario framework clearly outlines the multi-dimensionality of the problem. By providing researchers with multiple simulations based on this framework, with different SAI strategies and scenarios, it is easier to understand SAI potential.*

Walker Lee, recently graduated and now a Postdoctoral researcher at NCAR, has explored deeply the potential impacts of different SAI strategies in the Arctic (Lee et al., 2023a), highlighting the potentials to preserve permafrost but also the pitfalls of considering Arctic-focused interventions as "local", as even those strategies end up having global effects. Indeed, studying carefully the differential impacts depending on the injection strategy has been a big focus of the whole group this year: we have highlighted this both by looking at "single-point" injection simulations, not meant to represent actual SAI scenarios but performed in order to understand the sensitivity of the system to a specific perturbation (Visioni et al., 2023a; Bednarz et al., 2023a) and by analyzing, through those, the responses to more comprehensive strategies (Zhang et al., 2023), for instance on how they impact stratospheric circulation (Bednarz et al., 2023b) and on how they might preserve Antarctic ice shelves (Goddard et al., 2023), by affecting Southern Hemispheric circulation.

For the latter, Paul's paper has also strongly underscored how pointless it is to discuss whether SAI can, or can't, help preserve the ice sheets without being explicit about how much cooling SAI is meant to do, and on the specific strategy. The sensitivity of our simulated results to the cooling amount has been another strong focus. It is becoming increasingly clear that, when discussing the impacts, we need to be clear about what we are comparing our SAI simulations with: a hypothetical world where carbon emissions never happened, a past period with similar global warming as the one we're aiming for, or the future we're trying to avert (Visioni et al., 2023b)? This can have real impacts when discussing outcomes on things that are closer to people's concerns, such as agricultural yields: Rutgers researchers leveraged our simulations to highlight that, while a world where global warming does not continue is generally better for most of the world's crops, they might disagree on what the "optimal" amount of cooling might be (Clarke et al., 2023). Ewa also pointed out how much the magnitude of cooling (and therefore, the aerosol load) would impact stratospheric ozone (Bednarz et al., 2023c), and Walker has done the same discussing how much the simulated altitude of injection matters (Lee et al., 2023b).

A lot of our results are obtained using the Community Earth System Model (CESM) in its high-top configuration (WACCM), a state-of-the-art version of the popular climate model that Dan also helps maintain and keep updated (Davis, Visioni et al., 2023). Having a model that the group is experienced in using gives us lots of space to experiment and explore: however, we know that no single climate model is perfect, and one way to help assess the robustness of our results is to assess whether they are reproducible in other models as well. We've covered lots of ground in this aspect too this year. Ilaria, who has worked with Dan during her PhD, has joined our lab as a postdoctoral associate. She has experience with SRM and with comparing multi-model results of volcanic eruptions in order to understand sources of uncertainties (Quaglia et al., 2023). On the SAI front, based on our analyses of single injection locations in four models (Visioni et al., 2023a; Bednarz et al., 2023a), we have collaborated with other teams around the world to replicate our analyses in other climate models. This has led to a similar set of simulations using our scenario framework in UKESM (Henry et al., 2023), and with more models lining up to try and replicate our analyses (from the US, Switzerland, Japan…). This will mainly be possible thanks to the great framework that is the Geoengineering Model Intercomparison Project (GeoMIP), of which Dan is co-chair (Visioni et al., 2023c), and that is a great tool to foster international collaborations and legitimize our work on the international stage. The 2023 meeting in Exeter, organized by Dan in collaboration with the University of Exeter team, has been the largest GeoMIP meeting ever with over 100 participants (Visioni et al., 2023d). Next year, we'll hold the meeting in Ithaca in the summer to make sure our contribution to the field can be even more cutting, and to try to connect the Cornell community with our work further. Speaking of 2024…

What's in store for 2024?

Aside from the GeoMIP meeting, we have much more in store for 2024. Our team is working to keep highlighting the nuances of different scenarios, by wrapping up work on distinguishing and evaluating different injection strategies (with Yan Zhang, recently graduated), looking at how important the simulated starting year for SAI is (with Ezra Brody), trying to figure out how to expand this space even further through the use of emulators (with Jared Farley), and by exploring other connected risks in our framework (such as concurrent volcanic eruptions, with Ilaria). We're strengthening our Cornell effort with new hires (at the graduate and postgraduate level), and also working with a growing group of undergraduate students eager to get their hands dirty. GeoMIP work is continuing as we prepare for CMIP7, by proposing new, shared scenarios that can be fitted into future IPCC work, and this will be aided by our work with emulators, and by our constant collaboration with other modeling groups and intercomparison projects, too many to count!

We're also looking around for new science opportunities, such as exploring the impact of changes in shipping fuels and how that helps us think about detection and attribution of climatic signals, or what we can learn from wildfires. The interconnections with our work are many and all exciting, and we are bursting with new ideas.

Our impact inside and outside Academia

The issue of SRM is definitely one that is interesting from an academic point of view, but we always try to go beyond that. How do we communicate this issue to more than just fellow academics? We've definitely spread our research far and wide in many departments, with invited talks to U. Chicago, Louisiana State U., American U., KIT, NCAR and NOAA. We've also offered our expertise by serving as experts in panels hosted by the NASEM, Livermore National Labs, NASA, NOAA, RFF and by strongly collaborating with DEGREES to strengthen ties with researchers in the Global South. Dan and Doug also often talk to the press about our research, and SRM more in general (a few examples here, here and here), with the aim of educating public communicators about the importance of SRM research (something for which Dan has also helped spearhead a public letter of support for more research worldwide, here).

Believe it or not, this is a good fraction but not all the work we've done. There is a growing potential for our group to keep doing transformative research in this field, and we're working hard to make a difference. Stay tuned for 2024!

Our group at Cornell

Doug MacMartin - Associate Professor, Sibley School of Mechanical and Aerospace Engineering
Dan Visioni - Assistant Professor, Department of Earth and Atmospheric Sciences

Ilaria Quaglia - Postdoctoral Associate since February 2023
Illeana Gomez Leal - Incoming Postdoctoral Associate starting January 2024

Ezra Brody - PhD student in MAE
Jared Farley - PhD student in MAE
Yan Zhang - Former PhD student, graduated in 2023

Kion Yaghoobzadeh - Undergraduate in EAS
Alison Mangano - Undergraduate in MAE

Mengying Zhao - Visiting PhD student from Zhejiang University, Hangzhou, China

External Collaborators

Walker Lee - Former PhD student, now Postdoctoral Associate at NCAR
Ewa Bednarz - Former Postdoctoral Associate, now Research Scientist at NOAA
Ben Kravitz - Longtime collaborator, Assistant Professor at Indiana University
Paul Goddard - Assistant Research Scientist at Indiana University

Our 2023 research

Potential Non-Linearities in the High Latitude Circulation and Ozone Response to Stratospheric Aerosol Injection, Bednarz, E. M.,Visioni, D., Butler, A. H., Kravitz, B., MacMartin, D. G., and Tilmes, S., Geophysical Research Letters, 50, e2023GL104726, https://doi.org/10.1029/2023GL104726.

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For the general public

The Geoengineering Question, Project Syndicate

Q&A: What you need to know about reflecting sunlight to cool Earth, Cornell Chronicle

Stopping geoengineering, by accident, Catalyst with Shayle Kann

Fire smoke dimmed the sun. Scientists see research opportunities, New York Times

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