PLOS Climate

ESSAY

Why we need to explore conflict and competition around solar geoengineering

Ina Möller[1*], **Danielle N. Young**[2]

1 Environmental Policy Group, Wageningen University and Research, Wageningen, The Netherlands,
2 School of Politics and International Studies, University of Leeds, Leeds, United Kingdom

* ina.moller@wur.nl

Abstract

In an increasingly aggressive international political environment, solar geoengineering needs to be reconceptualized – not only as a response to climate change, but as an instrument of power. This conceptualization means going beyond focusing on cooperative scenarios in which the technology is used to effectively reduce temperature rise while minimizing potential side effects. As scholars of international relations, we see a need for more interdisciplinary engagement with solar geoengineering scenarios that explicitly feature political conflict and competition. By anticipating and exploring these, we can better contribute to informing governance arrangements that might be able to prevent situations that undermine international political stability and efforts to address climate change.

Citation: Möller I, Young DN (2026) Why we need to explore conflict and competition around solar geoengineering. PLOS Clim 5(4): e0000869. https://doi.org/10.1371/journal.pclm.0000869

Editor: Pedro Fidelman, University of Queensland, AUSTRALIA

Published: April 1, 2026

Funding: The research time of I.M. is supported in part by a personal grant from the Dutch Research Council NWO [VI.Veni.221S.120] The research time of D.N.Y. is supported in part by the ARIA funded Strategic Foresight on Climate and Geopolitics: Toward Governance of Solar Radiation Modification (SAFEGEOGOV) project [FPCW-PR01-P02] The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Introduction

Solar geoengineering – or the idea to spread reflective particles in the stratosphere in order to induce global cooling – is, no doubt, a powerful technology (see Fig 1). Some scientists advocate for exploring it because it might offer a temporary fix in response to climate emergencies like tipping points [1,2], or reduce climate hazards as part of a long-term portfolio of climate action [3,4]. Compared to the slow pace at which emissions reductions and removals are taking place, solar geoengineering promises a relatively fast and cheap way to stabilize runaway global temperature, and is sometimes portrayed as a way to reduce pressure on the cost and need for rapid decarbonization [5,6]. With the help of just a few powerful actors, and with the right scientific guidance, the hope is that dangerous effects of climate change could be staved off for a considerable amount of time, despite only incremental advancement in the reduction of greenhouse gas emissions.

The potential power of this technology to reduce global temperatures makes solar geoengineering the material of a hero saga, but it also draws our attention to the inevitable role of the villain, and more interestingly, their mutual constitution. Recent scholarship in the field of political ecology and international relations has pointed out how contemporary modelling exercises around solar geoengineering fail to account

Competing interests: The authors have declared that no competing interests exist.

for deployment scenarios that are entirely unmotivated by concerns for the climate, and are instead driven by different logics, such as security or power [7–11]. One reason for why this might be the case is that the infrastructure needed for climate modelling is computationally expensive and can therefore only handle a handful of scenarios in a meaningful way (especially if researchers aim to improve the functionality of different models). In addition, the scientific environment in which contemporary solar geoengineering research has developed is much more closely linked to climate policy than security policy.

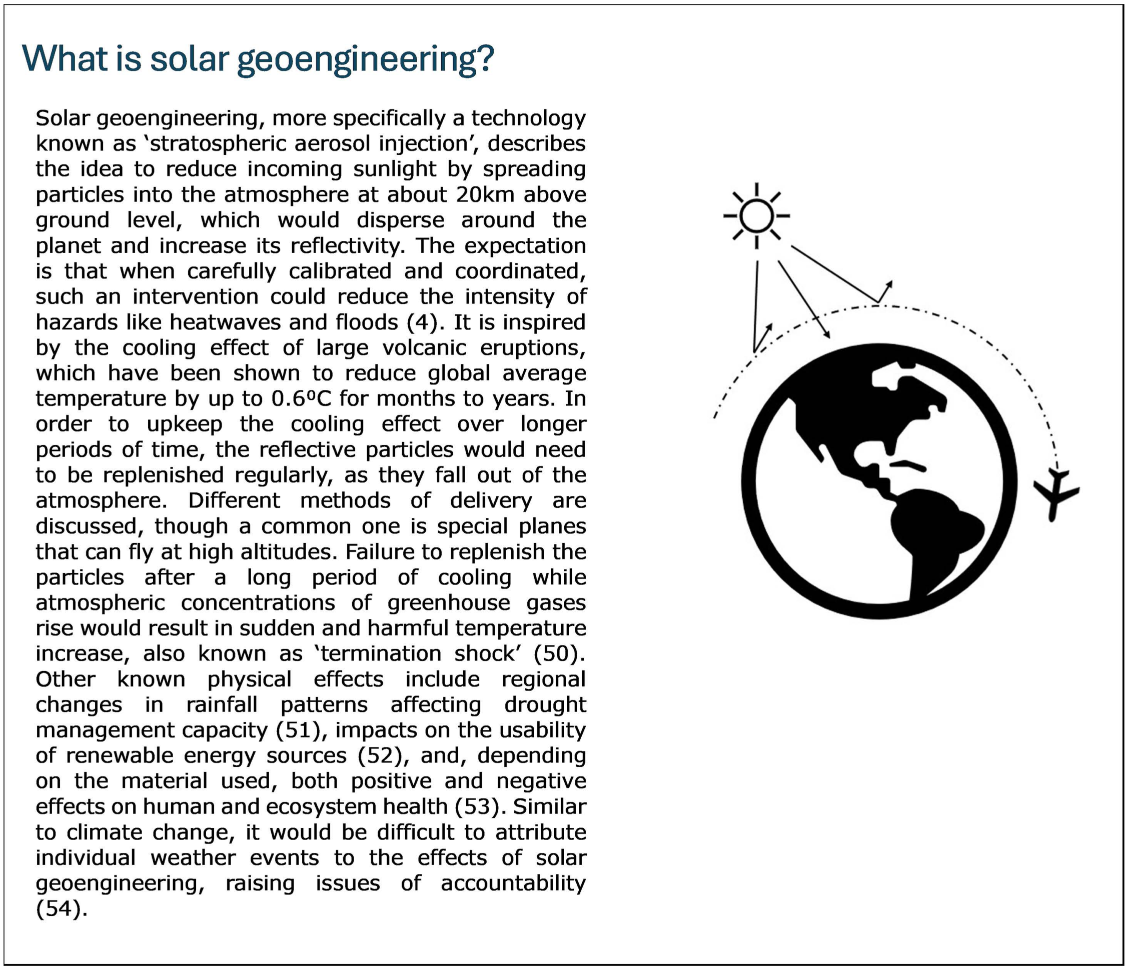
While we understand the infrastructural constraints around what is possible to model, we feel that the way in which solar geoengineering research is justified – namely as an issue of balancing risks – is incomplete if the argument refers to geophysical risks only. As scholars of international relations working in this field, we observe how solar geoengineering is often discussed with the understanding of it being a potential solution to climate change. In explaining why solar geoengineering research is necessary, research advocates tend to compare the risks of solar geoengineering to the risks of runaway climate change [12,13]. Such comparisons stay mostly in the realm of the geophysical, with little consideration for risk in the realm of the geopolitical [14].

Our understanding is that in order to fully assess the risks of this technology, we need to seriously engage with the systemic tensions that underlie our current international political environment and that by extension will shape the development and use of solar geoengineering itself. Effective governance and responsible research can *only* take place if we dedicate more focus to exploring scenarios in which solar geoengineering is conceptualized as an instrument of political power. This requires including the geopolitical system as a key component of solar geoengineering development and deployment scenarios, and calls for more interdisciplinary research in which the expertise of physical scientists is integrated with the expertise of political science and international relations.

In this perspective, we highlight some key geopolitical aspects that are likely to shape the use of solar geoengineering, and call for more focus on the research of scenarios that take these into account.

Solar geoengineering: A matter of competition rather than cooperation

In modelling exercises that aim for optimal solar geoengineering scenarios – those that limit global temperature rise while minimizing side effects – a core assumption is the ability and willingness of countries to act cooperatively over a period of at least 100 years, the minimal timeframe for solar geoengineering to keep global temperature from rising beyond 1.5C [15]. For solar geoengineering to function well, it is therefore dependent on institutions that are able to uphold global operations for centuries, and the existence of trust among the international community to ensure belief that whoever is conducting this operation is doing so with the best intentions in mind. Meanwhile, recent developments in international politics, such as the collapse of all nuclear arms control agreements [16] and the global increase in populist governments [17], remind us that such long-lasting institutions are rare [18]; that



What is solar geoengineering?

Solar geoengineering, more specifically a technology known as 'stratospheric aerosol injection', describes the idea to reduce incoming sunlight by spreading particles into the atmosphere at about 20km above ground level, which would disperse around the planet and increase its reflectivity. The expectation is that when carefully calibrated and coordinated, such an intervention could reduce the intensity of hazards like heatwaves and floods (4). It is inspired by the cooling effect of large volcanic eruptions, which have been shown to reduce global average temperature by up to 0.6ºC for months to years. In order to upkeep the cooling effect over longer periods of time, the reflective particles would need to be replenished regularly, as they fall out of the atmosphere. Different methods of delivery are discussed, though a common one is special planes that can fly at high altitudes. Failure to replenish the particles after a long period of cooling while atmospheric concentrations of greenhouse gases rise would result in sudden and harmful temperature increase, also known as 'termination shock' (50). Other known physical effects include regional changes in rainfall patterns affecting drought management capacity (51), impacts on the usability of renewable energy sources (52), and, depending on the material used, both positive and negative effects on human and ecosystem health (53). Similar to climate change, it would be difficult to attribute individual weather events to the effects of solar geoengineering, raising issues of accountability (54).

Fig 1. What is solar geoengineering.

https://doi.org/10.1371/journal.pclm.0000869.g001

international cooperation is a matter of constant negotiation [19]; and that trust in states' willingness to follow international norms is arduously gained and easily lost.

In a world where great-power rivalry is becoming increasingly commonplace, we need to assume that it is not cooperation, but competition that drives states to engage with solar geoengineering [20]. This also means that states may engage with it for reasons other than responding to climate change. A recent analysis by a UK security think tank has suggested, for example, that Russia could be interested in disruptive deployment of stratospheric aerosol injection for politically motivated purposes that are quite separate from climate considerations [21]. In US congressional hearings about solar geoengineering, questions have often been asked about whether or not rival powers are engaging with solar geoengineering research, not whether or how it could actually serve to combat climate change, or even what the focus/extent of other countries' research is [22].

Furthermore, it is important to remind ourselves that cooperation around solar geoengineering is not physically necessary for unilateral deployment. Some of those countries currently assessed to have the economic and industrial capacity to engage in large-scale, long-term solar geoengineering also have access to enough military and/or civilian territory worldwide to engage in the large-scale single hemisphere deployment needed for serious disruptive action [23]. The

United States has access to military bases and airstrips worldwide, enabling it to launch from anywhere in the world, with or without international cooperation. China's global investment in transport infrastructure under the belt and road initiative may put it in a similarly powerful position in the relatively near future.

Though the potential for 'rogue actors' who conduct solar geoengineering in an uncoordinated and undesired way is recognized as a problem in the solar geoengineering literature, labeling deviant uses of solar geoengineering as 'rogue' implies that they are outliers in an otherwise functional political system [24]. Given recent developments in international relations, we feel it is time to take competition and rivalry between countries as the starting point and see 'rogueness' as a defining feature of the political system that we currently live in.

Solar geoengineering and the potential for weaponization

Following the idea that competition has become a defining feature of the international political system, national security interests should move to the center of solar geoengineering research. This implies revisiting a currently widespread narrative among the solar geoengineering research community, namely that solar geoengineering cannot be weaponized, purportedly because it cannot be targeted at a certain region and because its hostile use would have negative effects on the user. This narrative builds on the common (dictionary) understanding that "weaponization" equates to an object being used to inflict harm on a discrete target. To revisit the risk of weaponization in solar geoengineering, we need to understand how the concept is used within the context of international security.

According to security experts, the ability to inflict physical harm on a *discrete* target is not necessary for the weaponization of a technology. Biological and chemical weapons, nuclear weapons, anti- personnel landmines and environmental modification techniques have all been cited by international actors in practice as examples of indiscriminate weapons with varying degrees of both use and agreed prohibition [25]. More directly relevant to solar geoengineering, or 'solar radiation management' (SRM), threatening to use (or withhold the use of) a powerful technology to manipulate or coerce the behavior of others is a kind of weaponization that is practically a commonplace in international relations. We can see this happening, for example, in the field of nuclear energy, where access to uranium enrichment technology is strictly controlled by some countries in an effort to coerce the behavior of others, often in the name of international security, but as often with other intentions operating in the background.

In the field of SRM, research has also recently been published in which international relations scholars interviewed national security professionals about their assessments of SRM and found that 'In stark contrast to how they appear in the science literature, consideration of SRM technologies evoked imaginaries of weaponisation' [11]. In this work, national security professionals invoked comparisons with nuclear, chemical and biological weapons as being similarly difficult to spatially constrain and specifically raised the potential of SRM to act as a political weapon, explicitly invoking the potential for threats of weather and climate warfare [11].

This harkens back to the origins of climate intervention research (see Box 1). During the decades of the Cold War, both the United States and Soviet Union invested heavily in attempts to develop climate control capabilities [26,27] and militarized climate research was entwined with nuclear weapons research. As the recent work by Corry et al also highlights, national security professional assessment of SRM as a threat is not limited to the issue of controllability but also to issues of detection, attribution and broader concern that the technologies could disrupt perceptions of strategic balance [11]. What is hostile is thus a matter of perception and contestation between security and political actors.

Box 1. History of climate research and climate control

After the development of atomic weapons and their use on Japan, interest in harnessing and controlling other fundamental physical processes served as an important motivation for the development of meteorological science. This was specifically pursued as a means of developing effective climate and weather control [28]. This interest was advanced well before there was a clear understanding of the trajectories of climate warming due to the greenhouse gas effect. For several decades, the potential for militarization drove climate and weather modification research and was 'overwhelmingly understood as a space of contestation between two superpowers' [26]. Only as the implications of rising greenhouse gases and other challenges posed by wider environmental degradation began to be better understood, following the 1965 President's Science Advisory Committee Report on Atmospheric Carbon Dioxide commissioned by US President Johnson's administration [47], did that focus start to shift. There was also growing recognition of the potentially catastrophic consequences of tense security competition for supremacy over technological and scientific breakthroughs [26]. Environmental sciences were shaped by military priorities and military funding [29], but growing concern about atmospheric changes due to greenhouse gases and the unease about the risks of attempts to achieve environmental control in conflict, particularly as a backlash against US practices in Vietnam [48] led to a shift of position throughout the scientific community. While interest in environmental warfare never disappeared, steps were also taken by political leaders in the Soviet Union and the US to limit militarized, hostile climate interventions and weather modifications [26]. In 1974, the USSR proposed what became the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Convention (ENMOD). At the insistence of the US, the wording of ENMOD was diluted in such a way that it is generally not viewed as a legal obstacle to pursuing solar radiation modification [26,30–35], but the initial proposal would have effectively banned solar radiation modification. In any case, the introduction of ENMOD marked a shift towards a 'taboo' against seriously pursuing climate intervention research. This strongly persisted until increasing alarm about climate change led to an intervention from atmospheric chemist Paul Crutzen calling for renewed research. In addition, the language of ENMOD includes any plans for weather modification or climate engineering with the potential for 'widespread, long-lasting and severe' harms, and it has been argued that the ENMOD provisions for consultation of the parties will have to be revisited to determine whether the parties to the treaty assess whether any climate interventions are considered hostile [28].

Concerns with strategic balance and competition in all geopolitical, environmental and technological arenas has become a matter of explicit concern for the remaining 'great powers' over the past decade. For example, in a recent strategy update, the Pentagon released a 'Joint Concept for Competing' that specifically lists *both the technological and geophysical-environmental* as instruments of national power that should be leveraged to optimize competitiveness in the 'field of play' or competitive space in which international actors operate. It explicitly commits US armed forces to focus on expanding their competitive mindset and competitive approaches to exploit every arena, military or non-military, in which the US has an actual or potential advantage and every vulnerability of any adversary. The report embodies the view that strategic competition is an enduring and comprehensive condition that is not limited to success in potential military conflicts, but one in which "traditional boundaries between military and civilian, between peace and war, between environments, and across domains are increasingly blurred" [36]. This updated doctrine is directly focused on initiating and exploiting "change in the complex strategic environment to create the influence, advantage, and leverage necessary to pursue U.S. interests" [36] as understood by the Joint Forces.

The impetus for this updated Concept for Competing is driven by perceptions of a similar approach in potential geopolitical rivals, particularly China and Russia, where the goal is to engage in strategic competition to displace US primacy by exploiting sub-arenas of competition while attempting to avoid direct military confrontation. Any technology that has the potential to create large-scale, long-term changes in the atmosphere can certainly be categorized under this understanding of 'instruments of national power,' whether the purpose of its use is climate optimization or amelioration, or simply interference and a race for perceived control and superior capabilities.

In a similar vein, nuclear politics shows us that some states have no qualms about continuously threatening the use of a technology that would be extremely harmful to themselves as well as their opponents. While there has not yet been a case of a state using nuclear weapons in a way that would also physically devastate themselves, there have been a number of cases in which nuclear weapons states have prepared to do so as a result of either political miscalculations, technical errors or some combination of both [37]. What could easily have resulted in nuclear war was averted not through diplomatic skill, strategy, or effective procedures, but luck and intuition. For example, in 1983 a Soviet Air Force Lieutenant Colonel, Stanislav Petrov, chose not to report an incoming launch of five intercontinental ballistic missiles from the US higher up the Soviet chain of command because he correctly assessed that it was a technological malfunction of some kind, in this case the way that sunlight reflected off of high altitude clouds when they were aligned with Soviet satellite orbits [38]. Petrov is credited with averting nuclear war in a period when US-Soviet tensions were running particularly high and reports warning of incoming missile attacks would be seen as highly credible by both the US President and the Soviet Premier. Had Petrov followed procedure and reported the satellite warnings, experts agree that the likely outcome would have been to engage the 'launch on warning' protocols in the nuclear chains of command for both [39].

The notion that great powers who are engaged in tense strategic competition will not use solar geoengineering as a coercive diplomatic tool because doing so may also cause them physical harm is therefore questionable, and, as the work by Corry et al [11] shows, is explicitly questioned by security practitioners themselves. Given the current reassertion of competitive geopolitics among major powers, a race to develop or deploy solar geoengineering technologies for reasons largely untethered from, and even detrimental to, climate protection should not be discounted by the SRM scientific community, whose conceptualization of weapons is markedly different from security experts and practitioners.

Solar geoengineering and the use of scientific expertise

While some progress has been made in exploring non-ideal scenarios within the SRM modelling community [40,41], a key challenge to the serious modelling of more erratic forms of solar geoengineering is the computational burden involved with using full-scale climate models. Modelers who have started exploring this space therefore work with 'emulators', or simplified models that are able to explore a much wider set of scenarios. The results may be less precise, but they provide a way of estimating how different points of injection, across different time-scales, might affect a range of climate-related variables [42].

While climate emulators can help in gaining a better understanding of the physical risks of solar geoengineering, or just 'how bad' the effects of mal-deployment could turn out to be, it is also relevant to ask for what purposes they might be used. We see two important ways of using this knowledge for purposes that may not have been intended by the developing scientists: to emphasize the need for regulation (or even a moratorium) of research and development, or, more worryingly, to better estimate how a primarily self-interested (or even hostile) use of solar geoengineering might be designed. There is thus a need to tread carefully in this space, as scientific knowledge is not always used in the spirit of the scientists providing it.

Comparative analyses of government responses to the Covid crisis show us that there are important tensions between the rationalities of science and the rationalities of policy making. Particularly in times of crisis, scientific (i.e., 'hard science', and often quantitative) knowledge is turned to in order to legitimate political decision making, heightening the status of certain (individual) scientists who have an affinity for public speaking. At the same time, science and scientists get instrumentalized in the effort to justify a policy measure that is motivated by other interests, such as maintaining control or catering to a political base [43,44]. In this process, simple messages and simplistic monitoring tools are constructed and relied upon, which in turn obscure the complexity and contingencies inherent to any instance of crisis management. When scientific advisors differ in their opinions about what to do, as they inevitably will, this offers decision makers the opportunity to "'shop around' the scientific market place" in order to selectively find support for pre-determined policy choices [45]. And when scientists publicly disagree on what the most appropriate pathway is, this in turn opens doors to "post-truth politics" in which decisions are made based on faith, tradition or propaganda [46].

What the Covid experience teaches us in the context of SRM is that there is not only a need for anticipatory research on the 'vaccine' [47], but also the need for anticipatory research on the 'use of science' in motivating the choice to apply it [48,49] and – as we emphasize – the need to do so in a decision-making context that may be entirely disconnected from the initial governance goal. This requires taking one step back and looking not only at how SRM might interact with the climate, but how the generation and provision of knowledge about SRM might interact with political decision making at large.

Important inspiration for this kind of work can be found in literature on interdisciplinary crisis studies. Insights from crisis management in health and environmental disaster point to the practical need for pre-emptive interdisciplinary collaboration and education in order to be able to operate in times of crisis; to provide strategic (i.e., long-term perspective) advice; and to effectively communicate results. Importantly, this also involves considering longer chains of cascading consequences and using a systems approach in which human and natural systems are coupled [50,51]. At a more conceptual and reflexive level, inter- and transdisciplinary collaboration can help unpack what we mean by crisis in the first place, and how the concept is mobilized by different parties to gain power or move certain issues into the realm of emergency politics [52]. Both lines of scholarship are important for thinking about how knowledge on SRM interacts with decision-making in a context of increasing global competition and security rhetoric.

The need for interdisciplinary work on worst-case scenarios around solar geoengineering research and deployment

To reiterate, we need to let go of the assumption that solar geoengineering will (only) be used as a climate response measure. It is as likely that the technology will be used to realize other strategic interests, including maintaining control over a key international space, achieving a strategic advantage, or simply demonstrating power. In a context of increasing international competition, what scientists provide in terms of information may or may not be used in the way that they intended, and will most likely be cherry picked and re-interpreted according to what fits a pre-existing plan that may be quite unrelated to addressing climate change.

While scientists have no way of controlling what states do, states themselves *can* put in place measures to prevent the worst scenarios from happening. These include things as simple (but as difficult) as installing a hotline (mythically depicted as a "Red Telephone") that allowed for direct communication between the leaders of the United States and the leaders of the former Soviet Union during the Cold War, aiming to prevent potential miscommunication and consequently total nuclear annihilation. Yet in order to do so, it takes creativity to imagine what those worst scenarios could be, and sometimes fiction is needed to inform fact [53]. By openly and transparently thinking about worst-case scenarios in a broader sense, information that would otherwise be generated in secret is open to public scrutiny and can inform negotiations around governance mechanisms for solar geoengineering.

It is for this purpose – to help states build safety mechanisms – that we call on climate scientists to work together with political scientists, sociologists and experts in international relations to imagine worst-case scenarios. We see a need to channel mental and financial resources into coming up with the most undesirable situations that could arise from solar geoengineering research and development. And in doing so, we call on (at least some) modelers to depart from the idea that solar geoengineering will be used primarily to address climate change.

How to do this? Importantly, advancing studies on worst-case scenarios requires equal-footing and openness to novel ideas from all participating disciplines. Once this is enabled, a key challenge that we have encountered in our own interdisciplinary work is the difference in underlying assumptions about how the physical and the political world work, and the priorities that we assign within our own research. Whereas (in our personal experience), climate modelers often focus on the functionality of the model and the quantifiability of the input data, social scientists tend to focus on the complexity and contingency of human decision making. While modelers tend to overestimate the rationality and goal-orientation of governance processes, social scientists tend to underestimate the complexities, magnitudes and timescales of climate dynamics. It is only by discussing those underlying assumptions that we realize why we have such different approaches or understandings of the technology and its implications. Yet uncovering those differences, which we are often not aware of, requires continuous engagement in a conversation that is not easy to hold, given the different worlds of expertise that we live in.

What we need is an open space in which none of the participating researchers are bound to the expectations of their discipline, where all voices are listened to with respect, and in which we can bring our various experiences to the table without the need to produce a pre-defined product. Mutual understanding should be fostered outside the limitations of working groups or work-packages. Research questions need to remain open and be determined iteratively and collectively.

Through various experiences of inter- and transdisciplinary collaboration, we have found that one way of enabling an even-footed conversation between people with very different backgrounds is through game design. The format enables a common methodological ground in which everyone feels equally awkward. By inventing and negotiating simple rules and procedures that try to represent complex systems, it is possible to uncover where our differences in assumption lie and where they come from [54]. Other open formats like role play or storytelling may serve a similar purpose and can act as a helpful starting point for more advanced scientific collaboration. Subsequently involving policy practitioners from various areas of expertise (environment, security, trade, finance), or even novelists and film-makers, can cast further light on aspects and dynamics that the interdisciplinary scientific team themselves may not have thought of. And so, by creatively imagining and engaging with worst-case scenarios, we equip ourselves and decision makers to identify and address those situations that all of us would like to avoid.

References

1. Zhao M, Cao L, Visioni D, MacMartin DG. Response of Tipping Elements to Different Strategies of Stratospheric Aerosol Injection. Earth's Future. 2025;13(12). https://doi.org/10.1029/2025ef006736
2. Pflüger D, Wieners CE, van Kampenhout L, Wijngaard RR, Dijkstra HA. Flawed emergency intervention: Slow ocean response to abrupt stratospheric aerosol injection. Geophys Res Lett. 2024;51(e2023GL106132):1–9. https://doi.org/10.1029/2023GL106132
3. MacMartin DG, Ricke KL, Keith DW. Solar geoengineering as part of an overall strategy for meeting the 1.5°C Paris target. Philos Trans A Math Phys Eng Sci. 2018;376(2119):20160454. https://doi.org/10.1098/rsta.2016.0454
4. Irvine PJ, Keith DW. Halving warming with stratospheric aerosol geoengineering moderates policy-relevant climate hazards. Environ Res Lett. 2020;15(4):044011. https://doi.org/10.1088/1748-9326/ab76de
5. Baur S, Sanderson BM, Séférian R, Terray L. Change in negative emission burden between an overshoot versus peak-shaved stratospheric aerosol injection pathway. Earth Syst Dynam. 2025;16(3):667–81. https://doi.org/10.5194/esd-16-667-2025
6. Keith DW, Wagner G, Zabel CL. Solar geoengineering reduces atmospheric carbon burden. Nature Clim Change. 2017;7(9):617–9. https://doi.org/10.1038/nclimate3376
7. Young DN. Considering stratospheric aerosol injections beyond an environmental frame: The intelligible 'emergency' techno-fix and preemptive security. Eur J of Int Secur. 2023;8(2):262–80. https://doi.org/10.1017/eis.2023.4
8. McLaren D. "It's Not the Climate, Stupid": Exploring Nonideal Scenarios for Solar Geoengineering Development. Ethics Int Aff. 2024;38(3):255–74. https://doi.org/10.1017/s089267942400025x
9. Surprise K. Geopolitical ecology of solar geoengineering: from a "logic of multilateralism" to logics of militarization. J Polit Ecol. 2020;27:213–35. https://doi.org/10.2458/v27i1.23583
10. Sovacool BK, Baum C, Low S. The next climate war? Statecraft, security, and weaponization in the geopolitics of a low-carbon future. Energy Strategy Reviews. 2023;45:101031. https://doi.org/10.1016/j.esr.2022.101031
11. Corry O, McLaren D, Kornbech N. Scientific models versus power politics: How security expertise reframes solar geoengineering. Review of International Studies. 2024:1–20. https://doi.org/10.1017/S0260210524000482
12. Gruener D, Visioni D. We can safely experiment with reflecting sunlight away from Earth. Here's how. The Guardian [Internet]. https://www.theguardian.com/commentisfree/2026/jan/06/reflecting-sunlight-climate-crisis-heating 2026. 2026 January 16.
13. Segall C, Worthington B. Some want to ban vital geoengineering research. This would be a catastrophic mistake. The Guardian [Internet]. 2026 Jan 9 https://www.theguardian.com/commentisfree/2026/jan/09/geoengineering-research-greenhouse-gases-plan 2026.
14. McLaren DP. Reconstructing Risk–Risk Analysis to Support Effective Governance of High-Risk Climate Interventions. Eur J Risk Regul. 2025;16(4):1206–22. https://doi.org/10.1017/err.2025.10019

15. Baur S, Nauels A, Nicholls Z, Sanderson BM, Schleussner C-F. The deployment length of solar radiation modification: an interplay of mitigation, net-negative emissions and climate uncertainty. Earth Syst Dynam. 2023;14(2):367–81. https://doi.org/10.5194/esd-14-367-2023
16. Mackinnon A, Seddon M, Bott I. A world without nuclear arms control begins this week. Financial Times. 2026.
17. Wajner DF, Giurlando P. Populist Foreign Policy: Mapping the Developing Research Program on Populism in International Relations. International Studies Review. 2023;26(1). https://doi.org/10.1093/isr/viae012
18. Gray J. Life, death, inertia, change: the hidden lives of international organizations. Ethics Int Aff. 2020;34(1):33–42. https://doi.org/10.1017/S0892679420000052
19. Hurd I. The case against international cooperation. Int Theory. 2020;14(2):263–84. https://doi.org/10.1017/s1752971920000470
20. Nielsen J. The big green button: stratospheric aerosol injection as a geopolitical dilemma during strategic competition between the United States and China, and implications for expanding aerosol injection near-term research. Oxford Open Climate Change. 2025;1(5):1–12. https://doi.org/10.1093/oxfclm/kgaf009
21. Ince M. Unnatural Disasters: The Next Front in Russia's Hybrid War. https://www.rusi.org/explore-our-research/publications/commentary/unnatural-disasters-next-front-russias-hybrid-war 2025 November 20.
22. Schubert J. Engineering the climate: Science, politics, and visions of control. Mattering Press. 2021.
23. Horton JB, Smith W, Keith DW. Who could deploy stratospheric aerosol injection? The United States, China, and large-scale, rapid planetary cooling. Global Policy. 2025;16(4):514–24. https://doi.org/10.1111/1758-5899.70015
24. Surprise K, McLaren D, Möller I, Sapinski JP, Stabinsky D, Stephens JC. Profit-seeking solar geoengineering exemplifies broader risks of market-based climate governance. Earth System Governance. 2025;23:100242. https://doi.org/10.1016/j.esg.2025.100242
25. Customary IHL - Rule 71. Weapons That Are by Nature Indiscriminate. https://ihl-databases.icrc.org/en/customary-ihl/v1/rule71 2026 January 29.
26. Baskin J. Geoengineering, the Anthropocene and the End of Nature. Cham, Switzerland: Palgrave Macmillan. 2019.
27. Fleming JR. The pathological history of weather and climate modification: Three cycles of promise and hype. Historical Studies in the Physical and Biological Sciences. 2006;37(1):3–25. https://doi.org/10.1525/hsps.2006.37.1.3
28. Fleming JR. Fixing the sky: the checkered history of weather and climate control. New York: Columbia University Press. 2010.
29. Hamblin JD. Arming mother nature: The birth of catastrophic environmentalism. Oxford, UK: Oxford University Press. 2013.
30. Royal Society. Solar radiation modification: policy briefing. 2025. https://royalsociety.org/-/media/policy/projects/solar-radiation-modification/solar-radiation-modification-policy-briefing.pdf
31. Huynh HN, McNeill VF. The potential environmental and climate impacts of stratospheric aerosol injection: a review. Environ Sci: Atmos. 2024;4(2):114–43. https://doi.org/10.1039/d3ea00134b
32. Abiodun BJ, Odoulami RC, Sawadogo W, Oloniyo OA, Abatan AA, New M, et al. Potential impacts of stratospheric aerosol injection on drought risk managements over major river basins in Africa. Climatic Change. 2021;169(3–4). https://doi.org/10.1007/s10584-021-03268-w
33. Baur S, Sanderson BM, Séférian R, Terray L. Solar radiation modification challenges decarbonization with renewable solar energy. Earth Syst Dynam. 2024;15(2):307–22. https://doi.org/10.5194/esd-15-307-2024
34. Tracy SM, Moch JM, Eastham SD, Buonocore JJ. Stratospheric aerosol injection may impact global systems and human health outcomes. Elementa: Science of the Anthropocene. 2022;10(1). https://doi.org/10.1525/elementa.2022.00047
35. Keys PW, Barnes EA, Diffenbaugh NS, Hurrell JW, Bell CM. Potential for perceived failure of stratospheric aerosol injection deployment. Proc Natl Acad Sci U S A. 2022;119(40):e2210036119. https://doi.org/10.1073/pnas.2210036119
36. Joint Chiefs of Staff. Joint Concept for Competing. 2023. https://s3.documentcloud.org/documents/23698400/20230213-joint-concept-for-competing-signed.pdf
37. Sleight J. GlobalZero. Seven Things Mistaken for an Incoming Nuclear Attack | Global Zero. https://www.globalzero.org/updates/seven-things-mistaken-for-an-incoming-nuclear-attack/index.html 2016.2026 January 29.
38. Hoffman D. I had a funny feeling in my gut - Soviet officer faced nuclear armageddon. The Washington Post. 1999.
39. Morra BJ. The Near Nuclear War of 1983. Air & Space Forces Magazine. 2022.
40. Baum SD, Maher TM, Haqq-Misra J. Double catastrophe: intermittent stratospheric geoengineering induced by societal collapse. Environ Syst Decis. 2013;33:168–80. https://doi.org/10.1007/s10669-012-9429-y
41. Jones A, Haywood JM, Alterskjær K, Boucher O, Cole JNS, Curry CL, et al. The impact of abrupt suspension of solar radiation management (termination effect) in experiment G2 of the Geoengineering Model Intercomparison Project (GeoMIP). JGR Atmospheres. 2013;118(17):9743–52. https://doi.org/10.1002/jgrd.50762
42. Farley J, MacMartin DG, Visioni D, Kravitz B. Emulating inconsistencies in stratospheric aerosol injection. Environ Res: Climate. 2024;3(3):035012. https://doi.org/10.1088/2752-5295/ad519c
43. Hodges R, Caperchione E, van Helden J, Reichard C, Sorrentino D. The Role of Scientific Expertise in COVID-19 Policy-making: Evidence from Four European Countries. Public Organiz Rev. 2022;22(2):249–67. https://doi.org/10.1007/s11115-022-00614-z
44. Ban P, Park JY, You HY. How are politicians informed witnesses and information provision in Congress. American Political Science Review. 2022;117(1):122–39. https://doi.org/10.1017/S0003055422000405

45. Zaki BL, Wayenberg E. Shopping in the scientific marketplace: COVID-19 through a policy learning lens. Policy Design and Practice. 2020:1–18. https://doi.org/10.1080/25741292.2020.1843249

46. Lee MM. Covid-19: agnotology, inequality, and leadership. Human Resource Development International. 2020;23(4):333–46. https://doi.org/10.1080/13678868.2020.1779544

47. Jinnah S, Long JCS. Top lesson from COVID for solar geoengineering: Anticipatory research is needed. Front Clim. 2022;4. https://doi.org/10.3389/fclim.2022.997430

48. Buck H, Geden O, Sugiyama M, Corry O. Pandemic politics—lessons for solar geoengineering. Communications Earth & Environment. 2020;1(1):1–4. https://doi.org/10.1038/s43247-020-00018-1

49. Patrick H. Reflections on COVID-19 Adaptive Responses: Lessons for Solar Geoengineering Engagement as a Climate Intervention Strategy. AJGES. 2025;1(2):95–123. https://doi.org/10.31920/2978-3305/2025/v1n2a5

50. Machlis GE, Ludwig K. Science During Crisis: The Application of Interdisciplinary and Strategic Science During Major Environmental Crises. Understanding Society and Natural Resources. Springer Netherlands. 2014. 47–65. https://doi.org/10.1007/978-94-017-8959-2_3

51. Bandara T, Dhillon J. Developing the tools to manage complex crises: training students in interdisciplinarity. Pedagogy Health Promot. 2016;2(3):201–5. https://doi.org/10.1177/237337991561486

52. Bergman-Rosamond A, Gammeltoft-Hansen T, Hamza M, Hearn J, Ramasar V, Rydstrom H. The case for Interdisciplinary Crisis Studies. Global Discourse. 2022;12(3–4):465–86. https://doi.org/10.1332/204378920x15802967811683

53. Nanz T. The Red Telephone: A Hybrid Object of the Cold War. Disruption in the Arts. De Gruyter. 2018. p. 275–90. https://doi.org/10.1515/9783110580082-015

54. Lukosch HK, Bekebrede G, Kurapati S, Lukosch SG. A Scientific Foundation of Simulation Games for the Analysis and Design of Complex Systems. Simul Gaming. 2018;49(3):279–314. https://doi.org/10.1177/1046878118768858