CHAPTER 16

Solar Geoengineering as a Threat to Climate Security, Cooperation and State Sovereignty

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Abstract
Solar geoengineering, also known as solar radiation management, is a set of techniques seeking to artificially lower the global temperature. This chapter explores the various risks that these techniques pose to the security of populations and to states' sovereignty, i.e. their ability to ensure security on their own territory. A deregulation of the global atmosphere by the technical action of one or more states would have consequences for the economic, political, and security stability of all states. In the absence of any international legal framework, national security can be compromised by these techniques. Unravelling such risks is key in order to be prepared and monitor developing projects. Geoengineering will constitute a challenge in new and intangible ways, thus creating breaches in international law and openings for hybrid conflicts.

Keywords: climate, security, geoengineering, state sovereignty, international legal framework

16.1 Introduction

Solar geoengineering, also known as solar radiation management (SRM), involves deliberately increasing the amount of solar radiation reflected by the Earth to offset the warming caused by the soaring greenhouse gas concentration. Originally proposed by Soviet scientist Mikhail Budyko in the 1970s, solar geoengineering was brought into the public debate by Nobel laureate in chemistry Paul Crutzen in 2006. It was observed that atmospheric pollution increased the amount of solar radiation reflection. Paul Crutzen thus suggested replacing harmful atmospheric pollution with a deliberate injection of a smaller quantity of aerosols into the stratosphere to preserve this cooling effect. So far, stratospheric aerosol injection has been the most extensively studied solar geoengineering technique. However, solar radiation management (SRM) encompasses other techniques of varying invasiveness, ranging from increasing surface reflectivity (such as painting buildings white) to enhancing cloud reflectivity through cloud seeding.

SRM projects have recently been gaining increasing interest in developed, thus emittive, countries, particularly the United States, where Harvard University is developing the main research program on solar geoengineering: the Stratospheric Controlled Perturbation Experiment (SCoPEx). According to openly accessible data, the United States has indeed become the global leader in solar geoengineering research, thanks in large part to funding from philanthropists and private benefactors towards academic research projects (Stephens et al., 2021). Faced with the inefficiency of international climate governance, proponents of solar geoengineering, such as Gernot Wagner and David Keith, argue that it is imperative to master such techniques in order for them to be quickly implemented in the increasingly likely scenario where mitigation policies prove insufficient (Wagner, 2021; Keith, 2013). In this context, a research program on solar geoengineering options was deemed necessary by the National Academies of Science, Engineering, and Medicine (NASEM) in a report published in March 2021 (NASEM, 2021); and in March 2022, the White House Office of Science and Technology Policy launched a five-year research plan to explore these options.

Therefore, we can observe a form of normalisation of solar geoengineering projects within American research communities, which consider them legitimate research initiatives (Biermann et al., 2022). This normalisation aligns with a broader technoscientific approach to addressing climate change, at the expense of systemic solutions, and has led to tangible developments in this field. The aim of this chapter is to explore various risks that this approach poses to the security of populations and to states' sovereignty, i.e. their ability to ensure security on their own territory. In order to do so we take three consecutive steps. Firstly, we will examine the physical and moral risks solar geoengineering poses to climate security. Secondly, we will delve into its specific impacts on the territorial sovereignty of states. Lastly, we will assess to what extent solar geoengineering could seriously jeopardise international cooperation on climate policies.

16.2 A Threat to Climate Security

To date, physical risks associated with solar geoengineering techniques are poorly understood and still subject to exploratory studies in atmospheric sciences. The techniques involving particle injection into the stratosphere raise significant environmental and health uncertainties, especially due to the proposed active substances such as sulfuric acid, which is destructive to the ozone layer and highly toxic (Lawrence et al., 2018). Moreover, sulfur, a component of sulfuric acid, could later precipitate as acid rain, causing health problems and damage to local ecosystems (Chalecki & Ferrari, 2018). There are also uncertainties regarding the effects of solar geoengineering on weather patterns (Baughman et al., 2010) and agricultural production. In this regard, risks posed by solar geoengineering on food security are starting to be explored, but studies on the subject remain limited. Some studies highlight risks of reduced crop yields in regions heavily influenced by summer monsoon systems, particularly in East Asia (Robock et al., 2008; Tilmes et al., 2013). Another study suggests that by reducing available solar radiation on Earth, stratospheric aerosol injection could negatively impact crop photosynthesis (Proctor et al., 2018). A reduction in solar radiation would also affect solar energy production based on photovoltaics (IPCC, 2022, 1491). However, given the global scope of solar geoengineering techniques, the variability of both impacts across regions and intervention methods hampers a comprehensive understanding of the risks they entail. The effects of such techniques depend on numerous variables that determine their deployment, such as their place within broader strategies for addressing climate change, the materials used, the season, etc. (IPCC, 2022, 1489). Furthermore, studies on these techniques largely rely on difficult-to-verify numerical models. Therefore, it is possible that the risks associated with the proposed techniques may not be fully understood prior to their deployment (Oomen & Meiske, 2021).

Another significant risk in the context of solar geoengineering deployment is the risk of sociotechnical lock-in, meaning the adoption of an irreversible pathway of the developed techniques in this field (Cairns, 2014). In this scenario, technological developments could lock in sociotechnical entanglements closely tied to financial investments and political positioning, making it unlikely for the techniques to be abandoned, even in light of negative impacts evidence. This irreversibility, commonly observed in Western technological developments, is exacerbated in the context of solar geoengineering due to the “termination shock” (Parker & Irvine, 2018). If solar geoengineering were to be deployed and managed to temporarily neutralise global warming, stopping the deployment would lead to a sudden temperature increase. Since the lifespan of stratospheric aerosols is one to three years, the injection of stratospheric aerosols would need to be repeated annually (Niemeier et al., 2011). As for marine cloud brightening operations, continuous spraying of sea salts into the clouds would be required, as their lifespan is only about ten days (MacDougall et al., 2020). Thus, two risks emerge from the necessary continuation of interventions: heavy dependence on resource-intensive technological developments (financial, energy, and mineral resources) and the potential for rapid and devastating global warming if events like natural disasters or supply disruptions were to halt the deployment.

In addition to physical risks associated with solar geoengineering techniques, there is a “moral hazard” (Preston, 2013) that could arise from the deterrent effect of these techniques, specifically their existence in the collective imagination regarding mitigation and adaptation efforts. Since the early 2000s, this risk has been increasing due to the "technoscientific promises" made by their advocates and the speculative hopes they raise about the possibility of a technical solution to climate change. Indeed, these techniques' development relies on the promise that a disruptive technology will replace or supplement mitigation policies and system-level transformational change. This promise undermines commitments to mitigation (Asayama et al., 2019) and is echoed by certain industrial sectors, particularly the energy industry, in their search for technical alternatives to climate policies (Low & Boettcher, 2020). By suggesting that a technique could temporarily suspend global warming while carbon emission reduction policies take effect, it leaves open the possibility of postponing those policies. In this context, the moral hazard is even more significant when the effectiveness of the techniques is uncertain. A 2020 atmospheric science study precisely questions this effectiveness in the absence of carbon emission reductions, highlighting a structural climate element not addressed by solar radiation interventions: the impact of greenhouse gases on cloud cover, which deteriorates as these gases accumulate (Schneider et al., 2020). Increasing greenhouse gas emissions lead to cloud thinning – and, in extreme cases, cloud – reducing their ability to reflect solar radiation. Despite the implementation of solar geoengineering techniques, significant global warming can still occur if CO_2 continues to accumulate in the atmosphere.

In this sense, solar geoengineering cannot compensate for a delayed political response to climate change. Moreover, the risks associated with these techniques are multifaceted and not yet fully understood. They encompass environmental, health, agricultural, and societal dimensions. The environmental and health uncertainties arise from the injection of particles into the stratosphere, with potential repercussions on the ozone layer, ecosystem health, and regional climate systems. The agricultural risks involve potential reductions in crop yields, particularly in monsoon-dependent regions, and the adverse effects on photosynthesis and solar energy production. The societal risks include the possibility of irreversible technological lock-in and the moral hazard that diverts attention and resources from necessary mitigation efforts. Furthermore, the complex and global nature of solar geoengineering introduces challenges in comprehensively assessing its risks across different regions and intervention strategies.

16.3 A Threat to State Sovereignty

Given the current state of knowledge and the uncertainties surrounding solar geoengineering, it is crucial to approach its development and deployment with caution. Continued scientific research, rigorous risk assessment, transparent governance frameworks, and inclusive international dialogue are essential to navigate the complex and potentially far-reaching implications of solar geoengineering as a potential climate change mitigation strategy. We will nonetheless demonstrate that these conditions are not gathered, neither at the international nor at more local levels.

Experiments and observational studies, which are essential for understanding the risks involved, face challenges in materialising due to prevailing public opposition. The scientific uncertainties surrounding the effects of solar geoengineering and the issue of public acceptance are mutually reinforcing: the lack of adequate knowledge about potential impacts makes any field experimentation controversial, while controversies surrounding small-scale experiments hinder the acquisition of field knowledge. Indeed, the need for field knowledge is a key factor shaping current and future geopolitical tensions surrounding these techniques. These tensions are manifested through strong reactions from local actors who oppose any experimentation on their own territory. Populations' reaction to experimentation is the first level of political opposition and questions the validation scale (should a project be validated at the international, national or local level?). Opposition to geoengineering, which aims to modify the atmosphere, a global common good, becomes a divisive element on the international stage due to the absence of a global legislative framework. Several attempts at small-scale experimentation, such as SPICE and SCOPEX, have been halted. In the case of SCOPEX, the Sami people strongly opposed a balloon launch test planned to take place in Sweden in 2021. Private actors also engage in this field, and develop parallel projects, releasing minuscule amounts of particles in the atmosphere without permission and facing unanimous condemnation from the scientific community. One example is the American company Make Sunsets, which sold "cooling credits" corresponding to the release of a certain quantity of aerosols. The company conducted several launches on Mexican territory but relocated its operations to Nevada following condemnation by the Mexican government. The Mexican government has expressed its intention to ban all geoengineering experiments on its territory and is expected to become the first state in the world to develop geoengineering legislation. Another instance is Andrew Lockley, who conducted an experiment on British territory in collaboration with the company European Astrotech in September 2022. As part of this experiment, a balloon released several hundred grams of sulfur dioxide into the atmosphere. While the controversy surrounding Andrew Lockley's experiment highlights the highly sensitive nature of intervening in a global common, controversies surrounding the SCOPEX project and the Make Sunsets company emphasise the even greater sensitivity when such interventions occur from the territory of another state.

Solar geoengineering operations can thus be perceived as symbolically violating territorial sovereignty through the chemical modification of the stratosphere, which falls below the threshold that demarcates a state's airspace. The latter constitutes one of the challenges of international governance and state sovereignty enforcement: indeed, it is still under discussion whether this threshold is located at 80 or 100 km above sea level. The aforementioned experiments could have been taking place above this threshold and still affect the agriculture or the environment of neighbouring states underneath. Therefore, it is important to develop legal frameworks around such deployments and define limits with the current blurred lines calling for actions which could infringe state sovereignty, all the more when the state has not been informed of these activities.

Pushing further the study of sovereignty-related risks and global insecurity, the potential array of reactions of affected states are to be highlighted. Non-informed affected states could indeed react through intergovernmental organisations, mobilising the United Nations Security Council or calling up the ENMOD convention. This convention regulates the uses of environmental modifications for military or "hostile" purposes. Its ambiguity could nonetheless be used by geoengineering-supportive states, underlining their "peaceful" intentions (Raczek, 2022). As underlined before, transparent governance frameworks and inclusive international dialogue are essential to navigate the potential repercussions of geoengineering deployment. It is however necessary to acknowledge the difficulty, if not the impossibility, to find such agreements in the current geopolitical context.

Touching upon international security, based on limited available options for a country to halt the deployment of geoengineering technologies in the vicinity of its territory, one can imagine a military based reaction, a "focused strike" as suggested by Versen et al. (2021) aiming at the deployed geoengineering technology. The reduced concrete diplomatic action panel materialises military action as a considerable risk, which should not be misconsidered. In addition, the activity of the private sector in that matter being central, one could underline the need for every state to get national legal frameworks enabling state control over geoengineering projects. State sovereignty will indeed be assessed by its capacity to regulate activities conducted by companies acting or headquartered on its territory. Along the same lines, the question of the positioning of states regarding geoengineering proves to be a fundamental element in the equation: whether states approve or disapprove of geoengineering activities will condition their legal frameworks, their ability to intervene following the call of a third party or another country and their cooperation capabilities.

The topic is still being swept under the rug at the international level, and it is difficult to map out the positioning of countries with regards to this nevertheless critical issue: around 50 countries started working on geoengineering technologies, according to the World Meteorological Organisation (Raczek, 2022), developed countries the vast majority. The challenge of understanding who works on what, and to anticipate debates in intergovernmental arenas, needs to be overcome in order to prepare for a context in which unilateral action, often difficult to attribute, could lead to escalation, and in which state sovereignty will be threatened in an unprecedented manner.

Whether it be the social skepticism against local level experiments, blurred lines, and loopholes in the global governance of such technologies, crystallised geopolitical context, or the array of reactions to potential state sovereignty infringements, conditions of a safe and secure deployment of solar geoengineering technologies have not been gathered. As a result, each and every full-scale experiment conducted by the private sector or academia could lead to escalation and represent a security risk at the international level.

16.4 A Threat to Climate Cooperation

Considering the interest in using such technologies alongside the variety and difficulty of assessing associated risks, no international consensus has been reached, leaving these techniques under a legal loophole. Their implementation could nonetheless give rise to tensions and conflicts, given the lack of a global arena to democratically agree on their use. Their likely unilateral deployment could not only undermine international climate cooperation but also give rise to counter-geo-engineering operations, to reverse effects of the first deployment. These conflict risks are intrinsically linked to the global scope of solar geoengineering operations. A deregulation of the global atmosphere by the technical action of one or more states would indeed have consequences for the economic, political, and security stability of all states. In the absence of any international legal framework, state sovereignty is compromised by these techniques.

Solar geoengineering projects remain limited in number and unevenly distributed globally, primarily due to the substantial financial investment and technological advancements required. The United States is the largest funding source, with support from both the government (such as the NOAA project) and philanthropic organisations like Silverlining. Research projects are also being carried out in the European Union, China, and India. The dominance of Western countries in solar geoengineering perpetuates global climate inequality on multiple levels: Western countries bear significant responsibility for past carbon emissions, they possess greater financial and technological capacities to adapt to climate shocks, and they hold decision-making power and influence in global climate change governance. This development of solar geoengineering projects by the West reinforces control over present and future atmospheric conditions, leaving countries in the Global South less responsible for global warming with little control. These states lack the resources to conduct field research and are particularly vulnerable to potential climate disruptions resulting from atmospheric intervention. This is how

Biermann and Möller problematise the development of geoengineering as a process of "marginalization of the global South" and call for total political control by all states in the international community (Biermann & Möller, 2019). In their efforts to reduce or offset this marginalisation, developed countries also tend to establish or deepen dependencies on financial, scientific, and technological levels. For instance, the British NGO *DEGREES Initiative* is funded up to $2 million to develop expertise on solar geoengineering in the Global South. This demonstrates the continuation of a power imbalance for knowledge and atmospheric control. Such imbalance tends to be compensated by technology transfer and capacity building, nonetheless keeping the global order as it is.

This is challenged by the resistance of some Southern countries rejecting the technocentric vision of Western climate strategies. For example, African civil society organisations signed a letter last year urging the African Union to reject geoengineering in Africa. Such resistance is part of a broader resentment amongst Southern countries towards the historical responsibility of the West and its failure to reduce dependence on fossil fuels. Taken to the extreme, the resistance of certain states can transform into geostrategic competition, with the aim of achieving dominance in solar geoengineering technology, which would redefine climate influence. This competition would no longer solely rely on a state's capacity to lead climate mitigation policies but on its ability to offer a solution. China's increasing prominence in solar geoengineering reflects its ambition to play a decisive role in future climate negotiations, involving the multilateral deployment of solar geoengineering programs. This role would allow China to counterbalance Western influence while advancing its national interests and those of developing countries.

In a context that is highly conducive to tension, conflict and competition, solar geoengineering techniques require global governance under the control of multilateral institutions and effective monitoring and enforcement over the deployment of these technologies (Holahan & Kashwan, 2019). However, international law remains extremely vague on this point, and currently, no institution has the legal capacity to regulate international decisions regarding geoengineering. It is precisely in the absence of such governance mechanisms that the startup Make Sunsets was able to freely carry out several small-scale stratospheric aerosol injections (sulfuric acid) in Mexico, highlighting two types of risk: firstly, the physical risks discussed in part I, which would result from a unilateral and large-scale deployment of solar geoengineering techniques by a public or private actor; secondly, the risks of conflicts between the driving state of this deployment and states that have not given their prior consent described in part II. However, the establishment of governance tools is compromised by the desire of a number of states to deploy them without legal constraints. In 2019, Switzerland and nine other countries submitted a resolution proposal to the United Nations Environment Programme, which aimed to undertake an assessment of geoengineering options and their risks, citing the "precautionary principle." However, it was blocked by the United States, Brazil, and Saudi Arabia (Chemnick, 2019). With no consensus reached on this issue, it is inconceivable for the international community to agree on the deployment of a specific solar geoengineering process and technical details such as the mode of substance diffusion, quantity, and duration of deployment. Therefore, solar geoengineering projects pose serious challenges to global governance and, according to some authors, appear incompatible with democratic decision-making (Stephens et al., 2021).

In the context of a climate emergency, intergovernmental disagreement over the deployment of a solar geoengineering technique would not lead to its abandonment but rather to its implementation by a coalition of states or even unilateral implementation. Such a possibility, facilitated by the low cost of deployment, has been problematised by Wagner & Weitzman, who originated the concept of the "free driver effect" (Wagner & Weitzman, 2012). Specifically, these authors highlight the highly positive economic ratio between the costs of geoengineering deployment and potential benefits, particularly the cancellation of global warming coupled with the avoidance of mitigation policies. Furthermore, this effect benefits from a favourable context characterised by the "free rider effect": climate change is a collective problem, but in the short term, responding to it through mitigation measures does not serve the individual interest of anyone. It is within the framework of the widespread inaction that currently characterises the international community and in the absence of an effective governance framework technological developments in solar geoengineering proliferate.

Moreover, as the field is seemingly dominated by the United States, it is possible that they may take the lead in future unilateral deployment of geoengineering, with the risk that the technological management of climate change primarily serves US national interests (Stephens & al., 2020). The United States' interest in this research field is, in fact, linked to strategic perspectives related to preserving its economic and military hegemony. The successful deployment of a geoengineering technique would open the way for the expansion of fossil fuels, which support its hegemony while also providing a response to climate change, considered a national security threat by the US military. This explains the involvement of US defence, intelligence, and foreign policy institutions in the development of solar geoengineering within the framework of "militarization logics" (Stephens et al., 2020). Given the strategic nature of such technologies for the United States, it is also likely that competing powers such as China or Russia will develop similar technologies with the aim of rebalancing forces.

Such a race for solar geoengineering would inherently entail a significant risk of technical escalation if one technology were deployed. If a "free driver" were to initiate unilateral deployment, other states could deploy "counter-geoengineering" programs to respond to the initial deployment. Two forms of "counter-geoengineering" have been theorised: a "neutralization" form that would involve dispersing new substances to accelerate the atmospheric deposition of already dispersed substances, and a "compensation" form seeking to reverse the effects of the dispersed substances by injecting warming agents (particles or greenhouse gases) (Heyen et al., 2019). Thus, the atmosphere could become the theatre of singular confrontations involving interventions and counter-interventions for planetary cooling. Such confrontations could occur against the backdrop of ideological divisions concerning the solution to climate change, particularly based on the contestation of US technoscientific hegemony. In this sense, the potential deployment of solar geoengineering technology not only poses the risk of technical disruption of atmospheric phenomena but also an additional disruption within the framework of technological escalation, stifling any possibility of international climate governance in a highly conflict-prone context. Nevertheless, in the absence of any legal framework for regulating these technological developments and considering the reflections exposed on the free rider effect, it is highly likely that unilateral deployments, like the Make Sunsets initiative, will multiply, ultimately leading to a technological lock-in of solar geoengineering and a weakening of mitigation policies.

16.5 Conclusion

Geoengineering could thus lead to simultaneous environmental, social, and economic (through agriculture and tourism) issues, hampering human security with challenges never faced before. It is of paramount importance to assess both these risks and the governance problematics associated. The lack of an international framework is at the core of difficulties in terms of monitoring and control, opening opportunities for states and non-state actors to act unilaterally at the expense of neighbouring communities and countries. In this chapter, we have tried to underline the aforementionned risks, to highlight the lock-in trends which would be inevitably associated with the deployment of such technologies and the moral plea arising from a technological solution to offset our CO2-intensive economy. Furthermore, this chapter introduced various escalation risks to be considered as critically probable, from technical counter measures, injecting more chemicals into the atmosphere, when countries are equipped with such possibilities, to military-like "focus strike" responding to geoengineering by traditional weapons (missiles, rockets, drones) to damage, destroy and neutralise deployment infrastructures. We argue that geoengineering deployment in the absence of any intergovernmental framework represents one of the most threatening disruptions in the geopolitics of nature and a new risk for state sovereignty.

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