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Patchwork Ethnography of Solar Geoengineering

Looking for novel ways of counting the ripples of public perception

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Abstract

Solar radiation management (SRM) has been proposed as a potential method to offset the effects of global warming caused by increased greenhouse gas emissions. This controversial technology presents several environmental side-effects that are still poorly understood and entails an enormous challenge for international governance. Due to the planetary scale of SRM, an inclusive and global conversation is deemed essential for its effective governance. To this end, in the last fifteen years, a growing body of scholarly journals on public engagement with SRM has appeared. These studies are based on quantitative opinion surveys administered to large numbers of people or qualitative deliberative workshops and interviews with a small number of individuals. However, public perception research on SRM has been mostly limited to the Global North and predominantly assumed the Western liberal-democratic view as a benchmark. Because public opinion is essential to create an appropriate governance framework and because SRM will have a global effect if deployed, more inclusive research is needed to investigate the attitudes of people who do not share Western values. The present thesis provides a critical review of the literature on public engagement with SRM based on the post-colonial studies on geoengineering. Notably, the Confucian ethical framework will be adopted to nuance the results of past research that too often neglect alternative ontologies and worldviews. The analysis is also based on a survey of university students in China and Italy about their attitudes towards stratospheric aerosol injection (SAI), one of the most discussed SRM proposals. My results showed that Chinese students revealed a more positive attitude toward the potential of SAI deployment and outdoor research. I also found a different degree of trust toward the national authority that could lead to support of different forms of governance and widespread agreement on SAI governance principles, such as transparency, inclusivity, and the need for public participation in decision-making. My thesis suggests that an inclusive approach that attends to the cultural specificities of a more heterogeneous public might nuance our understanding of public perception and acceptance of SRM.

Introduction

Solar radiation management (SRM) has been proposed as a potential method to offset the effects of global warming caused by increased greenhouse gas emissions. It includes three main proposals that have been widely discussed in scientific debates: stratospheric aerosol injection (SAI), marine cloud brightening (MCB), and space reflectors (Royal Society, 2009).

SAI is the most discussed technique, and it is the main focus of the thesis. It consists of releasing sulfur dioxide (SO2) to enhance sulfate aerosol formation in the stratosphere which would have a scattering effect deflecting part of the sunlight away from Earth. MCB involves adding cloud condensation nuclei - likely sea salt – into the low-level marine cloud layer to produce a higher amount of droplets which would increase the reflectivity of clouds. Space-based methods propose to reduce the amount of solar energy reaching Earth by positioning sun-shields in space to reflect or deflect solar radiation (Royal Society, 2009). These controversial technologies – also known as solar geoengineering or albedo modification techniques - present several environmental side-effects that are still poorly understood and entail an enormous challenge for international governance. Due to the planetary scale of SRM, an inclusive and global conversation is deemed essential for its effective governance. To this end, in the last fifteen years, a growing body of scholarly journals on public engagement with SRM has appeared. These studies are based on quantitative opinion surveys administered to large numbers of people or qualitative deliberative workshops and interviews with a small number of individuals. However, public perception research on SRM has been mostly limited to the global North and predominantly assumed the Western liberal-democratic view as a benchmark. Because public opinion is essential to create an appropriate governance framework and because SRM will have a global effect if deployed, more inclusive research is needed to investigate the attitudes of people who do not share Western values. The present thesis provides a critical review of the literature on public engagement with SRM based on the post-colonial studies on geoengineering. Notably, the Confucian ethical framework will be adopted to nuance the results of past research that too often neglect alternative ontologies and worldviews. Confucianism has been the dominant Chinese philosophy for over two millennia and has deeply influenced other cultures around the Pacific Rim (Yu and Fan, 2007). Currently, leaders of East Asian governments have based their domestic and foreign policy on Confucian tenets, first and foremost the concept of harmony (Tao, 2010). The Confucian perspective might offer a different view of certain topics deemed universal in the Western academy, such as the notion of personhood, the primacy of practice, and the unity between humans and nature. The analysis is also based on a survey of university students in China and Italy about their attitudes towards stratospheric aerosol injection (SAI). The comparison between Chinese and Italian respondents has been conducted in light of the most recent literature on public engagement with science (PES) and on SAI theorizations of Confucian scholars (Wong, 2013, 2015, 2018). The survey is the first of its kind to address the Italian public and the results revealed a widespread unawareness of

geoengineering both among Italian and Chinese respondents. However, Chinese students have a more positive attitude toward the potential of SAI deployment and outdoor research. I also found a distinct degree of trust in the national government that may lead to favor the support of different forms of governance. The survey also aimed to assess students' views on the significance of public participation through the lens of Confucian ethics on personhood. Research findings revealed broad consensus on the principles of SAI governance, embodied by the Oxford Principles (2009), which emphasize transparency, inclusivity, and the necessity of public involvement in decision-making. My thesis suggests that an inclusive approach that attends to the cultural specificities of a more heterogeneous public might nuance our understanding of the ripples[1] of public perception and acceptance of SRM.

The present work is a patchwork ethnography developed through the collection and analysis of heterogeneous materials from different academic fields. I heard about geoengineering for the first time in a short tape titled *Bill Gates Wants to Shade the Sun?* It debunked widespread media headlines and conspiracy theories about the involvement of Bill Gates in a project that aimed at placing a huge mirror in the sky to block the sunlight to reduce global temperatures. The mysterious and God-like aura of this project caught my curiosity and I set off to produce my first article on SAI analyzing the pros and cons of this technology (Paris, 2023). Following this article, as a class assignment, I designed a video essay on a SAI project known as SCoPEX. In the presentation, SAI was framed as a quick-fix response to address the double bind between overpopulation and resource exploitation, conceptualized by Garrett Hardin (1968) as *The Tragedy of the Common.* Within that work, I relied on Ursula K. Le Guin's (1986) *Carrier Bag Theory of Fiction* to investigate the narrative that sustains, feeds, and popularizes geoengineering projects. This narrative is "very old, as old as the tale of Canin against Abele" and it is about action, heroes, conflict, violence, about a tool that forces energy outward. It is a story of the propagation of the Ascent of Man that has a fixed narrative shape: from here - climate warming – to there - climate cooling. Afterward, inspired by Mary Douglas and Aaron Wildavski's (1982) cultural theory of risk and my studies on climate science, I started to sift through the dominant[2] scientific literature on geoengineering – mostly about SAI – looking for

[1] A controversial topic such as SRM can be analogous to a stone thrown into a pond, creating ripples that extend outward, first impacting the immediate affected victims, then the responsible company or agency, and in the most severe cases, reaching other institutions and entire industries, triggering widespread consequences (Slovic, 2016).

[2] I use the term *dominant PES literature* instead of *Western PES literature* for the same reasons as provided in Liboiron *Pollution is Colonialism?* (2021). First, *dominant* clarifies and better articulates the power relations. Western publications have become dominant to the point that other ways of knowing, doing, and being are

bits and scraps about uncertainties and research assumptions, about how climate simulations sought to turn unknown unknowns into known unknowns (Rayner, 2015). Then, I began to practice with R coding to attempt to reproduce simple computations using large climate data, downloaded from the Earth System Grid Federation (ESFG). I aimed to combine the uncertainties shown in the models 'outputs with Douglas 'risk analysis. Reviewing the scientific literature and coding with R, I soon realized I had to give up such a project as it was beyond my Master's scope and my academic formation. Therefore, I turned to the more familiar social sciences and noticed a growing literature on public engagement with science (PES) to gauge laypeople's perceptions of geoengineering. I wanted to understand *how* the scientific questions, assumptions, and the uncertain results of model simulations were incorporated into public discussions.

The PES literature on geoengineering has been in continuous evolution since the Royal Society's canonical publication in 2009. In its initial stage, the field was dominated by Western scholars who limited their analysis mostly to the Anglosphere. Afterward, these studies decisively broadened their scope to incorporate a wider range of countries. During this second wave of the PES literature, researchers addressed previously encountered bias mostly focusing on how to present, frame, and unframe geoengineering discourses to their audience either through working group consultations or online surveys. When concerns of Asians, Africans, Latinos, local and Indigenous[3] people were included, however, PES scholars never abandoned a pre-given research methodology that referenced the Euro-American ethical standpoint, considering publications, institutions, knowledge, concerns, and moral issues within the Western framework (Wong, 2015). I pondered the implications of discussing the global issue of climate warming and its possible solutions from a fixed and unchallenged reference to the West. I then try to sew these gaps with different knowledge and perspectives to challenge PES literature's pre-given categories and boundaries (Günel et al., 2020). Notably, through the works of Japanese PES researchers, I became aware of different theorization standpoints of geoengineering advanced by Confucian ethicists and Indigenous philosophers that remained unaddressed and unaccounted for in the dominant PES literature. Studies on public perception of SRM conducted in Bangladesh (Bostrom et al., 2011), China (Visscher et al., 2017), Mexico (Baum et al., 2024), Canada, and the US (Baum et al., 2023)

deemed illegitimate or erased. Second, not all PES scholars in Europe and America use the West as method (see Gannon and Hulme (2018), and Preston and Carr (2018)).

[3] Indigenous peoples are the living descendants of the pre-colonization inhabitants of lands now occupied and dominated by other groups. This definition is adapted from Whyte (2012).

maintained a rigid reference to the Western perspective when analyzing public responses, attitudes, and feelings toward SRM. These academics did not acknowledge the non-dominant views of Potawatomi philosopher K.P. Whyte (2012, 2018) and Confucian ethicist Pak-Hong Wong (2012; 2013; 2015; 2018) who wrote about geoengineering offering a very different account of how a diverse – that is non-dominant – ethical standpoint might perceive the idea of deliberately modifying the climate system.

The remainder of the thesis is organized as follows. Chapter 1 provides a background overview of SRM. This introduction offers a short history of climate modification and outlines the current scientific debate in Western academies. Despite the general public unawareness, SRM is not a new idea, but it has remained a taboo topic and a largely unresearched area until the early 2000s when Nobel Laureate Paul Crutzen argued that emissions abatement efforts "have been grossly unsuccessful" advocating the serious consideration of using SRM to compensate for the increasing warming of temperature caused by the anthropogenic greenhouse effect (2006: 211-212). More recently, several groups in the UK and the US have begun to advocate for more robust research into SRM to achieve the climatic goals set in the Paris Agreement (Felgenhauer et al., 2022). The current Western academic context of SRM research is characterized by two opposing viewpoints (Rayner, 2015). On the one hand, supporters of SRM advocate for outdoor research to proceed in order to collect more reliable scientific data that could deliver solid and comprehensive knowledge to improve the governance of future implementation (Parson and Keith, 2013). In contrast, opponents of all research on SRM – distinguished into computer simulations and outdoor field trials – argue that the uncertainties associated with the climatic and ecosystem responses of sulfate aerosol injection and other methods are so massive that could not be properly represented in any computer modeling (Hulme, 2014). Moreover, these scientists fear that conducting small-scale open-field experiments could be the first step on a 'slippery slope' toward large-scale implementation (Asayama et al., 2017).

Chapter 2 provides a methodological analysis of the SRM governance debate based on post-colonial studies. Different analytical instruments have been employed to conduct this research. The chapter opens with a well-known case study of geoengineering research that highlights the importance of public participation, and specifically of engaging with the situated beliefs and values of all relevant stakeholders involved in or affected by the experiment (Gannon and Hulme, 2018). The ethical dimensions and moral implications of geoengineering research are examined through the framework of the ‘post-normal science’

(Rayner, 2015). This concept highlights the interaction between empirical facts and societal values, taking into account both the biophysical risks and the moral considerations of fairness and social justice associated with SRM. Following, I focus on the implication of the structural issue of 'epistemic violence' for the public debate on SRM. The concept, introduced by Gayatry C. Spivak more than forty years ago, highlights how colonized identities are constructed and marginalized (Brunner, 2021). The interplay of social, material, and global dimensions of epistemic violence has been addressed by postcolonial and feminist literature, particularly in Vandana Shiva's impactful work (2020). As a prominent Indian physicist and activist, Shiva delivered a powerful critique of solar geoengineering, exposing the hidden conflicts of interest between billionaires and scientists. Her insights compellingly underscore the urgent need to address the material dimensions of epistemic violence in our current debates about technology. Following, a care-based analysis of the role of problem definition of guiding governance will be provided. The care ethics approach was introduced by Preston and Carr (2018) in their insightful analysis involving interviews about stratospheric aerosol injection conducted in Kenya, the Solomon Islands, and the North American Arctic. The authors suggested the care approach to spot all those areas of recognitional injustice, that is the "institutionalization of subordination exhibited in 'patterns of representation, interpretation, and communication' displayed across society" (: 311). At the core of recognition there is the idea that a group or an individual needs to be adequately acknowledged. This section will be followed by a more descriptive analysis of the governance challenges and instruments related to SRM. The governance of SRM has been widely debated in several scholarly, policy, and media discourses (Reynolds, 2019). The Royal Society's seminal report clearly indicated that the most critical challenges to the successful deployment of geoengineering will be the social, political, ethical, and legal dimensions of regulations, rather than scientific and technical issues. Game theoretic analysis of SRM will be used to provide a compelling overview of the governance challenges (McEvoy et al., 2022). Following, I will present the most salient existing national and international regulations to be applied for the governance of SRM (Felgenhauer et al., 2022). These regulations will be weighed against the scientific uncertainties identified in the model simulations from the Geoengineering Intercomparison Project (GeoMIP), a coordinating framework created to carry out and standardize climate modeling experiments of solar geoengineering (Kravitz, 2011). Lastly, the research governance features of SRM will be analyzed (Bellamy et al., 2017) and discussed by referencing the unsuccessful outdoor

research attempt made by the SCoPEX project, which failed to engage all relevant stakeholders (Risse, 2023).

Chapter 3 provides a thorough analysis of the literature on public engagement with science. These studies scrutinize the public perception of SRM through organized working groups or online surveys. The chapter opens with an overview of the PES literature on geoengineering and provides the most salient results of these studies. This body of scholarly journals has undergone significant changes since the initial calls for public participation from the Royal Society's landmark report that provided a classification of various geoengineering proposals and highlighted the main governance challenges. Following, I highlight the most prominent trait of the evolution of the PES literature, defined as a process of "unframing" (Bellamy and Lezaun, 2017), that is the effort by researchers to expand and refine the discursive and analytical frameworks of public discussion. Following, two relevant features that emerged from my critical analysis will be presented: (1) the *closing down* of geoengineering proposals discussed during deliberative workshops and presented in online surveys; and (2) the *opening up* of a more heterogeneous participation not limited to Western countries. After this initial overview of the PES literature, an example of an analysis of public perception based on Confucian specificities will be provided. Insights derived from the Confucian worldview may offer a nuanced understanding of the results of studies based on public engagement activities that include China and other Confucian societies of the Pacific Rim. Following, Confucian ethics and its different conceptions of the notion of personhood are used to provide a different view of the value of public participation. Finally, an analysis of SRM acceptance based on the Confucian tenet of harmony will be provided. The harmony-based approach aims to multiply theoretical standpoints and provide alternative horizons and perspectives so that the understanding of the self may be transformed and subjectivity rebuilt (Chen, 2010). This approach allows us to consider the controversial dimension of acceptability of SAI from a distinct perspective.

Chapter 4 is designed to provide an initial analysis of past research biases, weighted against my own work, in order to present some preliminary results. These biases are related to how SRM is framed by PES researchers, including among others several discourse lock-ins that might influence public perception, such as the issue of framing SRM as a technique that would simply scale up natural processes, or as a solution to a climate emergency or to the political failure to undertake serious emission abatement. Finally, the survey results will be presented. The main findings include public concerns over climate change, the attitudes

toward SAI deployment and SAI outdoor research, the degree of trust in institutions, the perceived role of public participation in SAI governance, and ontological and epistemological considerations that may modulate the attitude toward SAI. Notably, my results tentatively indicate that the perceived prominence of practical knowledge over theoretical knowledge may be a cultural nuance stemming from a different epistemological view that might contribute to higher acceptance of SAI deployment as well as a more open approach – though mostly reluctant – for the support of outdoor research.

Background introduction on solar radiation management

A Short History of Climate Modification

Climate modification - or geoengineering - has a long-tethered history but the topic only recently re-emerged in scientific debates and within the STS literature. Science and technology historian James R. Fleming (2006) distinguishes three moments in which the modern idea of geoengineering sparked up in the fantasy of Western scientists. The first moment was the century of the 'rainmakers,' ushered in by James Espy's proposal in the 1830s to enhance precipitation by lighting huge fires and stimulating convective updrafts. More rainmaking proposals followed throughout the 19th century, such as the so-called "concussion theory" to artificially generate rain by large explosions. The second moment was initiated by Nobel Laureate Irving Langmuir and his associates at the General Electric Corporation who made promising discoveries in cloud seeding research, another rainmaking technology. In 1946, after noticing that dry ice dropped into a supercooled unit caused the formation of a cloud of millions of tiny ice crystals, Langmuir and his associates released six pounds of dry ice pellets into a cold cloud creating ice crystals along a three-mile path. Soon after that, cloud seeding was weaponized by the US military to harness "the violence of the atmosphere" and it reached a "macro-pathological turn" between 1967 and 1972 in the jungles over North and South Vietnam. Under the secret operation POPEYE, the US Air Weather Service "flew over 2,600 cloud seeding sorties and expended 47,000 silver iodide flares – an improvement of the dry ice - over a period of five years at an annual cost of approximately $3.6 million" (Fleming, 2006: 13). Besides early research into cloud seeding, in 1965 a proposal plan for managing solar radiation was drafted by US President Johnson’s

Science Advisory Committee to address the emerging issue of global warming. Staggeringly, the final report only considered what today we would call geoengineering without even mentioning climate adaptation and greenhouse gas mitigation measures (Rayner, 2015). Soon after, the first series of scientific research into solar radiation management (SRM) began (Marchetti 1977). It is noteworthy that despite today's skepticism and public unawareness of SRM, the climate policy of the United States conceived the possibility of managing solar radiation long before considering plans for adaptation and CO_2 mitigation. However, SRM remained a taboo topic, with "a wide range of conflicting assumptions" (Rayner, 2015), and a significantly underexplored area until the third and most recent moment of “promise and hype" of climate modification. In the early 2000s, speculative announcements concerning weather modification from various governments, organizations, and CEOs created a momentum for geoengineering research that reached an academic consensus after Nobel Laureate Paul Crutzen (2006) argued that emissions abatement efforts “have been grossly unsuccessful” advocating the serious consideration of using SRM to create aerosol clouds in the stratosphere to deflect part of the incoming solar light back into space, thus lowering global temperature (: 211-212). Notably, the Crutzen consensus referred to sulfate aerosol injection (SAI), one of the most studied SRM proposals.

Concrete funding and support to research, however, have started after the pledges of the Paris Agreement to keep “the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit warming to 1.5°C” (UNFCCC, 2024). Such an ambitious plan is considered “extremely unlikely” by a large part of the scientific community due to the steady increase in global CO_2 emissions – on average 1.7% annually since the first international climate agreement, the 1992 UN Framework Convention on Climate Change (UNFCCC) (Barrett, 2024). Facing the reality that curbing emissions is "nearly impossible," several groups in the UK and the US have begun to advocate for more robust research into SRM to achieve the climatic goals set in the Paris Agreement (Reynolds, 2019). The Royal Society working group (2009) called for a yearly £10 million investment for 10 years; while in the US, Harvard scholars suggested an initial $5 million expenditure into a phased research program to be gradually scaled up to $30 million (Rayner, 2015). The opportunity cost of these investments is relatively small for the UK and the US’s R&D yearly budget. Yet, the research that these expenditures support is highly controversial, revealing that concerns for geoengineering technology “go much deeper than the issue of the opportunity costs” (Rayner, 2015), encompassing issues of morality and attitudes towards the

environment that have profound repercussions for what we think it is to be human (Hulme, 2014). More recently, a report from the US National Academies of Sciences, Engineering, and Medicine (NASEM) proposed a $200 million investment into a research program to better understand the risks, benefits, and impacts of geoengineering strategies (Wells et al., 2024). The cornerstone for support of SRM research was the 2023 congressionally mandated report from the Biden administration "outlining an initial research plan into an initial governance framework for solar geoengineering" (Rovelli, 2023). These reports aim to establish a more robust assessment of the socio-ecological impacts of SRM and explore possible solutions for an internationally agreed governance framework. The latest Synthesis Report of the AR6 of the IPCC (2023) expressed with high confidence that SRM has the potential to offset global warming within a couple of decades and ameliorate some climate hazards, but it would not restore climate to a previous state. If SRM were globally deployed and then abruptly terminated in a high CO_2 emission scenario it would cause rapid climate change – so-called 'termination shock.' The IPCC highlighted with high confidence that increased CO_2 concentration and ocean acidification would not be halted by SRM. Finally, concerns for the governance implications of SRM have been raised in the Synthesis Report as well as by the European Union in the *Outlook on the climate and security nexus*, which reminded the importance of the precautionary principle in the assessment of climate modification techniques (Baum et al., 2024). Recent events, however, rendered SRM much less theoretical. Two separate groups in the UK and the US conducted small-scale field trials of SAI[4]. The first was conducted in April 2022 by a Silicon Valley start-up, Make Sunset, that released two air balloons in Mexico without prior government notice. There were several concerns over the expertise of the company CEO Luke Iseman and his associates and both supporters and opponents of SRM denounced the start-up's attempts to commercialize geoengineering research by selling *cooling credit* in the form of gift cards[5]. The second experiment was conducted by the independent researcher Andrew Lockley and the firm European Astrotech in England, in September 2022. The test included two trials that did receive a flight permit and adhere to common research standards (Temple 2023) but were not made public to relevant stakeholders (Baum et al., 2024). Both the name of the project -

[4] Besides these two, another completed SAI field trial was conducted in Russia in 2009. Also, Israeli company Stardust Solutions has plans for SAI field tests. Finally, two well-known failed SAI experiments are the SPICE and SCoPEX projects (ETC Groups, Geoengineering monitor).

[5] The company's website reads as follows: "Gift cards are perfect for eco-conscious friends, family, or anyone who dreams of a cooler future. Recipients can purchase Cooling Credits, offsetting the warming effects of CO_2 emissions by funding *real*, *measurable* deployments of SO_2 into the stratosphere (my emphasis).

SATAN, Stratospheric Aerosol Transport, and Nucleation - and the comment to the press (Temple, 2023) revealed the intent to be provocative. Both experiments were highly criticized by supporters and opponents of SAI and the government of Mexico became the first to ban open-field tests of stratospheric aerosol injection (Rodriguez and Lo, 2023).

Uncertainty

Among the dominant literature on public engagement with science (PES), geoengineering is standardly defined as "the deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming" (Royal Society, 2009). It includes a broad set of proposals divided into carbon dioxide removal (CDR) and solar radiation management (SRM). The first reduces CO_2 concentration in the atmosphere, and the second decreases incoming solar light deflecting part of it back to space (Felgenhauer et al., 2022). Both strategies are still largely theoretical and extremely controversial as they represent a Western industrial-based solution to a global issue that has been caused mostly by Western industrial activities. Notably, among SRM proposals, stratospheric aerosol injection (SAI) has been said to be relatively cheap, fast-acting, and close to being deployable (Barrett, 2007; Wigley, 2006).

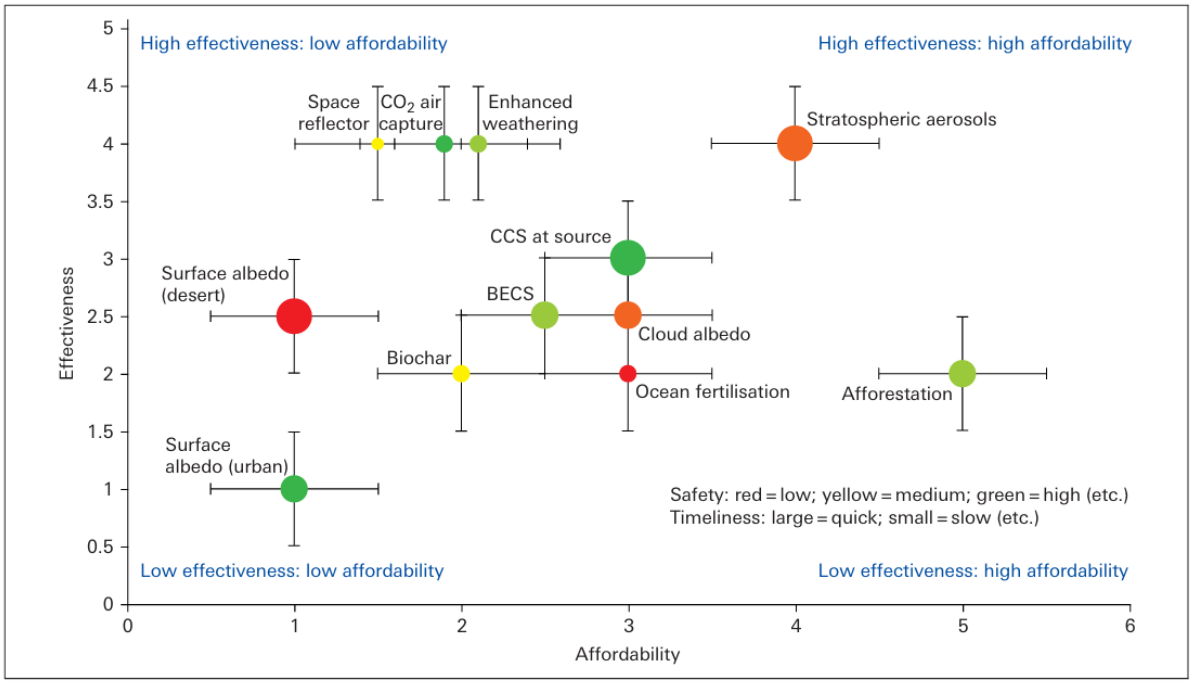

Figure 1: Preliminary overall evaluation of geoengineering proposals by the Royal Society (2009), (CCS = Carbon capture and storage; BECS = Bio-energy carbon capture and storage).

However, SAI represents a quick fix to global warming that could carry significant ancillary effects on local weather and ecosystems (Robock, 2008). Because of the high degree of

scientific uncertainty (IPCC, 2023), Western academics are divided into supporters and opponents of more robust research on SAI, especially open-field experiments (Rayner, 2015). The potential bio-physical effects of altering solar radiation pose a condition in which outcome probabilities cannot be assessed because there is ignorance and insufficient information. The concept of uncertainty therefore is to be understood in the Knightian sense, that is, unmeasurable uncertainty, or the absence of a single probability model for a stochastic event on decision-making (Xepapadeas, 2024). In contrast, the term 'risk' refers to measurable uncertainty, a situation in which probabilities can be assigned to events. In the IPCC context, however, uncertainty and risk are not distinct concepts and are based mostly on a heuristic and rule-of-thumb approach that provides descriptions of alternative scenarios characterized by two main metrics: confidence and likelihood. The probabilities linked to the manifold and multiscale socio-ecological impacts of SAI represent a situation of *deep uncertainty*, as described in Xepapadeas (2024), where the "decision-maker does not have the ability to determine a precise probability structure for the physical or the economic model" (: 4).

Although scientists' opinions are divided by the deep uncertainty of climate system internal feedback loops, both supporters and opponents of SAI agree that global deployment is unthinkable in the current state of knowledge. Among the strongest supporters of SAI outdoor research is North American engineer David Keith whereas British geographer Mike Hulme is an oft-cited opponent. Since the 1990s, Keith has argued for the importance of improving computer modeling along with small-scale experiments gradually and cautiously scale up over time (Keith and Dowlatabadi, 1992). More reliable scientific data could deliver sound knowledge to inform decision-making and improve the governance of future implementation. He suggested three near-term steps to break the deadlock in geoengineering research: accept government authority, declare a moratorium on large-scale experiments, and state a small-scale threshold below which outdoor research may proceed (Parson and Keith, 2013). On the other hand, Hulme argued that the "complexity and uncertainties inherent in the climate and ecosystems responses are so massive that even if they were better understood they could not properly be represented in any conceivable computer modeling of stratospheric aerosol deployment in the foreseeable future" (Hulme, 2014). Accordingly, conducting research would be a waste of resources and – worst – could be the first step on a 'slippery slope' towards large-scale implementation (Asayama et al., 2017). Moreover, Rob Bellamy (2017), a British researcher who has extensively explored the public perception of climate modification technology, warned that revealing the complexities and uncertainties may make

geoengineering science inscrutable to non-specialists, making it more complex to properly address and engage all relevant stakeholders.

Methodology

In recent times, constraints and limitations imposed by the COVID-19 pandemic and long-established feminist and postcolonial theorizations have demanded a rethink of how knowledge is produced and shared in globalized yet differently situated socio-political and socio-ecological contexts. To address such emerging challenges, anthropologists Gökçe Günel, Saiba Varma, and Chika Watanabe (2020) conceptualized a new methodological approach known as *patchwork ethnography* that defies the "fixity, holism, and certainty demanded in the publication process." The concept refers to a methodological framework that adopts fragmentary yet rigorous data and maintains "the long-term commitments, language proficiency, contextual knowledge, and slow thinking that characterizes so-called traditional fieldwork." Patchwork ethnography broadens the range of materials, tools, and subjects we consider acceptable for analysis. This approach rethinks the linearity of research: from data collection to result analysis. This methodological framework fits properly the current debate on SRM research as it is about exploring the implicit *hows* onto which research ethics is founded. *How* do we learn? *How* is knowledge distributed in different regions of the world? *How* does a patchwork approach change the way we think? *How* do knowledge gaps and limitations become the inspiration for new insights?

The present thesis is based on a patchwork ethnography developed through the analysis of scientific, economic, and social studies. Notably, insights about the critical scientific uncertainty of SRM have been derived from the publications of the Geoengineering Model Intercomparison Project (GeoMIP), a coordinating framework created to carry out and standardize climate modeling experiments of solar geoengineering (Kravitz, 2011). Climate model standardization is the best way to identify the potential sources of differences among model responses and diagnose model-dependent factors in order to reduce the deep uncertainty associated with SRM (Visioni et al., 2024). These uncertainties refer to the potential biophysical impacts of SRM, including regional climatic variability, pressure gradient perturbations, stratospheric ozone depletion, and effects on marine and aquatic biodiversity (Robock, 2008). The governance of research and anticipatory governance of deployment have been deemed essential either to enable or restrict the future use of SRM

(Gupta et al., 2020). Therefore, several studies have been undertaken in the last twenty years, particularly after the recommendation of the seminal report on geoengineering published by the Royal Society in 2009. The social sciences inform the debate on SRM through various approaches that can address knowledge gaps in the governance, attend to the situated relations of humans, technologies, and their environment, and translate people's anxieties and attitudes toward climate change and SRM (Aldy et al., 2021). The primary analysis of this thesis is based on the literature regarding public engagement with science (PES) that explored public perceptions of SRM through studies conducted via workshops or online surveys.

I sought to gain a deeper understanding of how the assumptions and uncertain outcomes of model simulations were effectively woven into public discourse. This thesis presents a critical review of the literature on public engagement with geoengineering, drawing on Confucian, feminist, and post-colonial theories. The rationale of my work aligns with the historical lineage of Standpoint theory, an organic logic of research that reemerged in the 1970s and 1980s as a feminist epistemology, philosophy of science, sociology of knowledge and methodology (Harding, 2004). The Standpoint approach as described by American philosopher Sandra Harding seems particularly relevant for the present thesis as it critically engages with geoengineering science in two ways. It asks *whose knowledge is being produced. Who will share the benefits and who will bear the costs?* In Harding's words, it scrutinizes "the inadequacy of sciences' standards for achieving objectivity or good method, and how the plausibility of these standards has been maintained" (2003: 26). In addition, contrary to dominant epistemology that views politics and local knowledge as a hindrance to scientific inquiry, through standpoint theory the situatedness of epistemic location and political struggles galvanize the growth of knowledge.

The main analysis of the thesis spans a diverse array of studies on public perception of SRM, from the foundational works of the Royal Society to the most recent publications (Baum et al., 2023; Low et al., 2024) that investigated public attitudes toward climate modification technology across twenty-two countries. Despite the broader engagement of public workshops and online surveys, the theorization of solar geoengineering proposed by non-Western academics remains largely unaddressed and unaccounted for in the dominant PES literature. The choice of this methodological approach has important implications for the governance process of SRM as it is informed by a research paradigm that refers only to Western values and does not attend to other cultural traditions. The research criteria that emerged from this framework are those deemed important by the Western perspective, such

as economic growth and social progress, democratic governance, national defense, and the politics of the nation-state, while situated cultural values and beliefs may be neglected and erased. Throughout the thesis, citations will include several Asian and other non-Western scholars to demonstrate a postcolonial effort in my methodology that, as suggested by Métis scientist Max Liboiron, “refuses to reproduce the myth that knowledge and particularly science, is the domain of pale, male, and stale gatekeepers” (: viii). For world knowledge production, ‘the West as method’ is the global condition, sometimes interpreted in different ways: an opposing entity, a system of reference, a goal to catch up with, an intimate enemy, and an alibi for serious discussion and action (Chen, 2010). In this context, Asian post-colonial literature plays a vital role in enriching theoretical perspectives, challenging geopolitical dominance, and illuminating marginalized and overlooked knowledge. This endeavor, epitomized by the concept of "Asia as method" (Chen, 2010), serves as a powerful tool for contesting Western cultural hegemony by positioning Asia and the Third World as critical points of reference (Anderson, 2012). Rather than outright rejecting the West, this approach advocates for a more equitable and tactical engagement with it (Anderson, 2012). "Asia as method" provides a compelling heuristic to identify alternative loci of enunciation and ethical frameworks for research, particularly in addressing the significant knowledge gaps within the dominant research on public engagement with SRM. Amid this framework, I will use the Confucian ethical perspective to offer a novel interpretation of some prevalent findings in the dominant PES literature. These include grappling with the dimensions that constitute public acceptance, the ethical dilemmas associated with human hubris and the argument of 'playing God,' the public attitudes towards open-field experimentation, and the role of public participation in the governance of emerging technologies. By reframing these discussions through a Confucian lens, we can foster a deeper understanding of the ethical implications, cultural specificities, and obligations involved in shaping future relations among humans, technology, and the environment.

Another fundamental instrument that enriches the patchwork ethnography of this thesis is the concept of "post-normal science," proposed by Rayner (2015) within the framework of the sociology of ignorance to delve into the ethical dimension and moral implication of SRM. Originally introduced by Funtowicz and Ravetz in 1985, this concept can be effectively illustrated by the two orthogonal dimensions of 'systems uncertainty' and 'decision stakes.' The framework represents the interplay between empirical facts and societal values (Funtowicz and Ravetz, 2003). The dimension of 'systems uncertainty' focuses on the

quantification of risks and the accuracy of estimates and measurements, while 'decision stakes' addresses the technical evaluations of benefits and costs, alongside moral considerations of fairness and social justice. The post-normal science framework advocates for a "unified conception of problem-solving" across these dimensions, highlighting the importance of recognizing "the plurality of legitimate perspectives on any problem." This transformative approach encourages open dialogue, mutual respect, and collaborative learning, ultimately enhancing our capacity to address complex and controversial issues (Funtowicz and Ravetz, 2003: 4), such as the governance of SRM.

One more indispensable instrument of my methodology is “the care approach” developed by Preston and Carr (2018) to assess the (un)justice of climate engineering with stratospheric aerosol. The authors used this approach to conduct a structured interview about SAI in Kenya, the Solomon Islands, and the North American Arctic. Their method focuses on justice, but it does not narrowly look at the distribution of benefits and harms. Distributional justice does not consider how societies and cultures are structured, but it makes justice appear as a matter of benefits and burdens sharing. Individual or group recognition is a key indicator of questions of just distribution. Failure of recognition is often the result of "the institutionalization of subordination exhibited in patterns of representation, interpretation, and communication displayed across society" (: 311). Ensuring recognition means working to understand the situated concerns, the different starting assumptions, values, and knowledge practices related to the idea of geoengineering the climate. The care approach goes beyond questions formulated within the scientific ‘normal’ paradigm and it looks for answers not only about the distribution of climatic benefits and burdens – such as reduced precipitation, cooler temperature, increasing amount of erythemal UV radiation, etc. – but also addresses politics and culture. For example, it includes historical circumstances that have disadvantaged certain groups, the requirement to carefully listen to marginalized voices, and the necessity of identifying the structural injustices that sustain subordination. This approach emphasizes relationships, context, dependence, power/vulnerability, affect, and narrative, areas that traditional assessments of political justice have tended to overlook (Preston and Carr, 2018). The main criticism raised to this methodological approach is that it is insufficiently normative to outline how policymakers should emphasize such areas of recognitional justice. It emphasizes emotions and relationships but lacks clear procedures for handling emotional conflicts or managing curtailed relationships. Similarly to the ‘post-normal’ science framework and the standpoint of ‘Asia as method’, the care approach does not provide

definitive answers about what is just or unjust but it focuses on bringing attention to particular areas of concern through a series of targeted questions about relationships, context, power, dependence, affect, and narrative. The authors argued that “the answers to these questions will reveal whether or not recognitional justice is likely to be served by a given deployment of climate engineering.”

Finally, after identifying some of the dominant PES research gaps, I crafted a comprehensive survey first in Italian and then translated it into Chinese, aiming to investigate the different perspectives on geoengineering between Western and Confucian views. I acknowledge that, despite my best efforts, the survey quantitative analysis will primarily compare the responses of Chinese and Italian participants, highlighting a divide between the Rest and the West, which may inadvertently position the Western perspective as the normative standard. To counteract this limitation, several questions rooted in Confucian philosophy have been added to the survey, addressing crucial topics such as the human-nature relationship, the concept of personhood, epistemological attitudes, and social justice. A key section titled *Ontological Paradigms* specifically assessed public perception from a Confucian ethical viewpoint, and I was particularly interested in analyzing how Italian responses contrasted with this different ontological understanding. I believe my thesis not only provides insights but also serves as a resource for future cross-cultural comparisons among diverse countries and sub-populations, engaging meaningfully with the situated beliefs and values of local communities (Gannon and Hulme, 2018).

Post-colonial analysis of geoengineering governance discourses

The sine qua non for geoengineering governance

Building on Andy Stirling's (2008) critique of "opening up" the governance of science and technology and his proposed three rationales for participatory processes in early technological appraisal, Frumhoof and Stephens (2017) defined three objectives or "intentions" to legitimate the strengthening of "systematic engagement processes" in the governance of solar geoengineering. First, the authors identified a "normative intention" as a broad public engagement in developing SRM research norms and guidelines increases its legitimacy and "is the right thing to do." Second, public participation warrants an

"operational intention" as failing to establish a legitimate collaborative research process with all the relevant stakeholders could jeopardize responsible societal considerations on SRM. Lastly, the "substantive intention" of including and attending to diverse perspectives and expertise will favor a better research design and "a stronger capacity to equitably inform diverse societal goals." Furthermore, the role of the public in the environmental governance has been institutionalized in the Arhus Convention which aims to protect the right of all individuals to live in an environment adequate to their health and well-being. It is the only legally binding legislation on environmental democracy that puts into practice Principle 10 of the Rio Declaration which states that environmental issues are best handled with the participation of all concerned citizens, at the relevant level (UNEP).

The pivotal role of public participation in geoengineering governance has also been highlighted by Kate E. Gannon and Mike Hulme (2018) in a study on Indigenous appraisal of the ocean fertilization experiment designed by the Haida Salmon Restoration Corporation at Haida Gwaii, Canada. The controversial test was conducted by a rogue American businessman who dumped around 100 tonnes of iron sulfate into one of the world's most celebrated biodiverse Indigenous lands to spawn an artificial plankton bloom that would have re-stocked local salmon population. The experiment not only lacked transparency and inclusiveness, but it also infringed a de-facto moratorium on geoengineering outdoor research issued in 2010 by the UN Convention on Biological Diversity (CBD) and it violates the London Convention on the dumping of wastes at sea, which prohibits for-profit ocean fertilization activities (International Maritime Organization, 2024). While outlining the project to relevant stakeholders, the rogue actor misled Haida Indigenous leaders, hiding any potential side effects and managing to receive a substantial investment from the Haida Corporation. Gannon and Hulme conducted a series of interviews among local residents to gauge the public perception of the project, aiming to provide “a useful benchmark for reflexivity in geoengineering governance.” In their findings, they remarked that “engaging with the situated beliefs and values that underpin human attitudes and responses towards novel geoengineering technologies is a sine qua non for good governance.” Excluding humans’ "situated beliefs and values" in the early technological appraisal may easily perpetuate and reinforce existing asymmetrical power relations (Whyte, 2018). Vulnerable populations have expressed the concern that geoengineering technology would amount to another excuse for the rich nations to take control of poorer countries (Preston and Carr, 2018). Indigenous people are particularly relevant in early technological appraisal as their

experiences come to climate engineering refined by centuries of dispossession and exploitation. Through their ethnographic engagement with Q-methodology, the authors identified three distinct viewpoints on iron fertilization – that also "emerge across a range of other geoengineering technologies – that reflect "different ideas held by local residents about planetary limits, about the way humans attain knowledge of natural systems and about the human values of, ans responsibilities toward, nature" (: 1). They hope the Haida Gwaii's case study will become a salutary lesson for future governance of geoengineering where existing inequalities are not exacerbated but where Indigenous voices and perspectives are used as a valuable analytical instrument for weighing in on a range of ethics and justice issues serving as benchmarks, lessons, and opportunities.

Post-normal science

The oft-cited 'moral hazard' of spraying sulfate particles to let industries continue business as usual is one of the core topics against SRM research (Sugiyama et al., 2016). More accurately, this problem has been defined as emissions abatement displacement[6] (Reynolds, 2019) and it refers to the potential of SRM to lower the overall risks of climate change at much less cost than mitigation does (Felgenhauer et al., 2022). It could potentially lead decision-makers to reallocate their efforts away from mitigation and towards SRM. Recently, the growing literature on geoengineering produced outside Western academies, however, has indicated a different ethical dilemma, pointing to the paucity of voices in geoengineering debates that do not belong to the Christian, Caucasian, and Colonial traditions (Whyte, 2018). Most of the authors cited until now belong to a Western stage from which the alternative views and different concerns are silenced, unheard, or instrumentally deployed (Wong, 2015; Whyte, 2012). However, it is noteworthy that not all Western scholars neglect and suppress alternative perspectives. The Oxford principles[7] for geoengineering governance proposed by a group of distinguished academics at Oxford University in 2009 laid the groundwork for an inclusive approach in the SRM debate. This proposal attempted to capture all the relevant implications for societal values and the situated cultural beliefs that are to be included in the decision-making (Rayner et al., 2013). These Principles were further nuanced and extended

[6] In the language of economics, this issue is more specifically referred to as the 'crowding out' of emission mitigation incentives (McEvoy et al., 2023).
[7] Five Principles laying down the basic parameters for decision-making on SRM: (1) geoengineering to be regulated as a public good; (2) public participation in decision-making; (3) disclosure of geoengineering research and open publication of results; (4) independent assessment of impacts; (5) governance before deployment.

by American philosopher Stephen Gardiner into the Tollgate Principles (Gardiner and Fragnière, 2018) that introduced robust action-guiding prescriptions for the governance of SRM.

Steve Rayner, the lead author of the Oxford Principles, provided an insightful framework to better understand the social dilemma posed by SRM. Referencing the sociology of ignorance, Rayner (2015) proposed the concept of "post-normal science" to better understand the ethical dimension and moral issues of geoengineering. The notion was first proposed by Funtowicz and Ravetz in 1985 and it can be represented on two orthogonal axes with the dimensions of 'systems uncertainty' and 'decision stakes' (Figure 2), that is facts and values (Funtowicz and Ravetz, 2003). The first includes the quantification of risks and the precision of estimates and measurements whereas the second represents the technical assessments of benefits and costs and moral concerns about what is fair and socially valued. The post-normal science framework "unified conception of problem-solving" in these dimensions and promotes "the plurality of legitimate perspectives on any problem," leading "to a focus on dialogue, and on mutual respect and learning, wherever possible" (Funtowicz and Ravetz, 2003: 4).

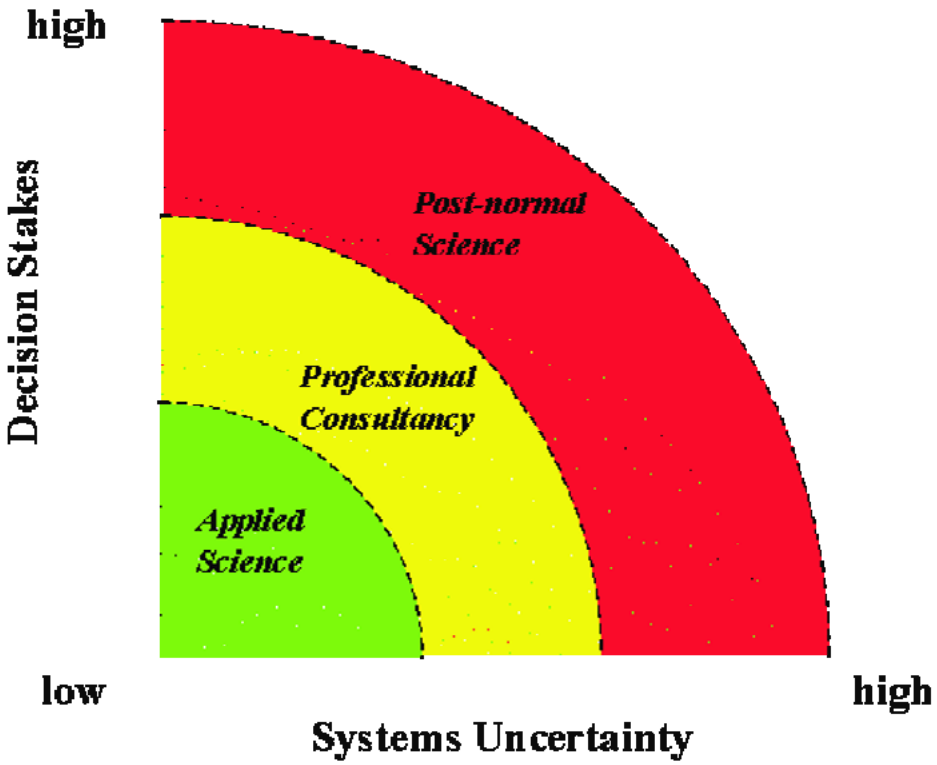

Figure 2: The diagram of post-normal science from Funtowicz and Ravetz, 2003: 4.

When both dimensions are low, we are in the safe space of 'normal' science, where decision-making is represented by standardized procedures. When either is medium, routine

techniques are not enough: technical skills, creativity, and even courage are required. In the case of SRM, both dimensions are high as there is *deep uncertainty*, and the decision-making process “is dominated by the competing worldviews of the people involved and is likely to be conducted in an adversarial mode.” This mode belongs to the post-normal science approach, and it is made up not only of technical and scientific knowledge but also entails competing rhetorics of SRM that “embody fundamentally different worldviews about what it means to be human and our relationship with nature” (Rayner, 2015). Both indoor and outdoor research of SRM attempt to reduce ignorance and uncertainty with the purpose of also clarifying the decision stakes. However, according to the post-normal science framework, concerns of SRM opponents go beyond the potential bio-physical hazards of global deployment but include questions about the moral permissibility of engineering the atmosphere and the kind of world we want to live in. Through the post-normal science framework becomes possible to attend to the specificities of the non-Western public whose standpoint is unlikely to be affected by more robust research. The term ‘post-normal’ points rightly to the rejection of research “normally consisting of puzzle solving within the framework of an unquestioned and unquestionable paradigm” (Funtowicz and Ravetz, 2003: 5). Indeed, for many, geoengineering is incompatible with their own worldview and, as Rayner concludes, they may see the lack of knowledge as a guiding policy and ignorance as “a virtue that preserves us from folly” (2015: 8).

Violence

The post-normal science framework extends the research paradigm, overcoming the limit of considering an "unquestioned and unquestionable" Western perspective. Since most of the dominant scientific research is still conducted within the limit of 'normal science,' in many SRM discourses the cultural, philosophical, and socioecological contexts that matter to the current climate discussion are unaccounted for. These accounts are "vital for members of another society to experience themselves in the world as having responsibilities to other humans, nonhumans, and the environment” (Whyte, in Liboiron, 2021: 88). Across a broad spectrum of disciplines, non-Western authors exposed the entanglement between knowledge and power and demonstrated how foreign thoughts must be filtered through white intermediaries (Todd, 2016). The understanding of European power as a regime of truth that allows Western universal claims to make sense, circulate, and act as truth, while others do not, has been first elaborated by French historian Michel Foucault through the concept of power/knowledge (Liboiron, 2021). The notion emphasizes that knowledge is not neutral but

is produced within power relations that shape what is considered true or false, normal or abnormal, and influence how people behave and think (Gaventa, 2003). Power is exercised through control over discourse – who gets to speak, what can be said, and how it is said.

Aware of the relationship between power and knowledge, Asian scholars have advocated for some time the urgent need within the academy to "de-universalize, provincialize, or regionalize the West" (Chen, 2010: 218). In the essay *Provincializing Europe: Postcoloniality and the Critique of History*, Indian historian Dipesh Chakrabarty argues: "In the academic discourse of history – that is, 'history' as a discourse produced at the institutional site of the university – 'Europe' remains the sovereign, the theoretical subject of all histories, including the ones we call 'Indian', 'Chinese', 'Kenyan', etc." (1992: 337). The citational fetishism of scholars in the Global South is not reciprocated by Euro-American academics. Chakrabarty explains that the contradiction from such citational asymmetry is that "for generations now, philosophers and thinkers shaping the nature of social science have produced theories embracing the entirety of humanity. As we well know, these statements have been produced in relative, and sometimes absolute, ignorance of the majority of humankind - i.e., those living in non-Western cultures" (1992: 3).

Among the de-colonial critique and postcolonial literature, the complicity between knowledge and power has been defined by feminist Gayatry C. Spivak as epistemic violence: "the remotely orchestrated, far-flung, and heterogeneous project to constitute the colonial subject as Other" (in Brunner, 2021: 195). Thirty years after Spivak's canonical definition, an increasing number of voices from global sociology and other disciplines have pointed at the deeply colonial heritage of the Western academic system and the Eurocentric scholarly sphere. Austrian feminist and peace scholar Claudia Brunner (2021) analyzed different modes of how epistemic violence is explicitly or implicitly brought up across a broad spectrum of disciplines. Relevant to my analysis is the connection of the social, material, and global dimensions of epistemic violence highlighted in the postcolonial and feminist literature, particularly in the works of Vandana Shiva (2020). The Indian physicist and activist aptly explored the materialistic dimension of epistemic violence. She argues that the logics pertaining to the neoliberal society - capital accumulation, profit maximization, nature exploitation, and imperial militarism – hold responsibility for the grave reduction of scientific knowledge and human capability of understanding the world by excluding and destroying all other ways of knowing. In *Oneness vs the 1%* (2020), Shiva vociferously denounced SRM and pointed to the conflict of interests between billionaires and scientists. Her work revealed

how corporations in the IT and biotechnology sectors enlarge their empires through free trade, neoliberal policies, and the deregulation of commerce. Geoengineering is described as one of the most irresponsible experiments, largely financed and lobbied by Bill Gates, Murray Edwards, and other billionaires. The SCoPEX project was indeed largely financed by Gates who invested more than $4.6 million into David Keith's research at Harvard University. Keith further receives an undisclosed sum from Gates each year and is the president of the geoengineering company Carbon Engineering, largely financed by Gates and other private investors. Keith's colleague Ken Caldeira from Standford University also receives yearly support of $375 000 from Gates and he is employed by Intellectual Ventures, a private geoengineering company part-owned by Gates and run by Nathan Myhrvold, former head of technology at Microsoft. The company has also applied for patents on techniques to geoengineering the stratosphere. In an interview with The Guardian, Diana Bronson of ETC (Action Group on Erosion, Technology, and Concentration) said:

There are clear conflicts of interest between many of the people involved in the debate. What is really worrying is that the same small group working on high-risk technologies that will geoengineering the planet is also trying to engineer the discussion around international rules and regulations. We cannot put the fox in charge of the chicken coop.

In a press release for her new book[8], Shiva denounced the hubris of philanthrocapitalism that is being used to find new ways of manipulating the climate and weather. She referred to the deep uncertainty of stratospheric aerosol injection and described it as part of the "mechanistic reductionist paradigm that treats living organisms, including the Earth, as machines that can be engineered." Because of this, she consciously avoided the term Anthropocene as she perceives it at the base of the current ecological destruction." To continue putting humans at the center of consciousness is to perpetuate human hubris." Anthropocentrism represents the last stage of the Western paradigm adopted in the 'normal science' framework, including ethnocentrism, colonialism, industrialism, and capitalism. She called this the rule of the 1% that neglects not only the rights of all non-human beings but also those of most human beings themselves.

British-Australian feminist Sara Ahmed goes on to institutionalize "the white men" describing it as a "persistent structure or mechanism of social order governing the behavior of a set of individuals within a given community" (in Todd, 2016: 12-13). Moreover, the

[8] *The Nature of Nature: The Metabolic Disorder of Climate Change* (2024).

institutionalized white men need to reproduce themselves through "mechanisms that ensure the persistence of that structure." This reproduction is citational (Todd, 2016) and it can take the form of a screening technique where "certain bodies take up spaces by screening out the existence of others" (Liboiron: viii). As Métis anthropologist Zoe Todd bluntly put it "One must cite white men to get ahead" (2016: 13). In his insightful research on how references to Indigeneity are brought up in geoengineering discourses, Potawatomi philosopher Kyle Whyte (2018) provides three examples of how Indigenous voices and concerns are implicitly or explicitly addressed in official debates. First**,** Indigenous views are elicited when Western scholars aim to gauge whether alternative perspectives "offer insights or reasons that can weigh in on what is known or debated about the ethical acceptability and justice of geoengineering." Most often, scientists resort to Indigenous considerations when they seek moral approval or a broader understanding of the ethical acceptability of SRM. This is clearly stated in a 2012 report from the UNCDB, claiming that Indigenous perspectives may be gauged to root decision-makers proposals within a broader framework and to incorporate a holistic approach into their work (Whyte, 2018). The second example refers to discussions about the history of the very idea of geoengineering. Among the supporters of SRM outdoor research, there is a tendency to conflate deliberate global climate change with unintended transformations of nature from hunter-gatherer societies. Consider the words of David Keith:

"While global-scale transformations are a recent consequence of industrial civilization, human transformation of nature is ancient. Some transformations are deliberate, such as the use of fire by aboriginal peoples who altered landscapes to suit their needs or even the modern use of dams to create new lakes. Other transformations occur as an unintended side effect of resource use, such as the mass extinctions of Indigenous fauna by early hunters in Australia and the Americas or the more recent threat of climate change caused by our use of fossil energy" (Whyte, 2018: 294).

The inclusion of Indigenous stories of hunting, fire management, and river damming is "to suggest that it is precisely Indigenous peoples' histories - among others - that show us how normal it is to deliberately change the environment at large scales." Another similar case is provided by Oksanen (2023) in reference to reindeer grazing by the Sámi people. Recent research confirmed that millions of kilometers of natural reflective surfaces are endangered by creeping treelines and the systematically directed reindeer grazing by the Sámi has contributed to halting albedo reduction, maintaining vast reflective surfaces that could otherwise have been lost. The author concludes that:

"*If the discussion begins with acknowledging all the valuable ways with which they contribute to managing the ecosystem and by extension the climate, and how these practices can be protected and further expanded, it is much more likely that Indigenous peoples can see value in interventions that manage the climate*" (: 10).

As Whyte argues, "these authors seem to point to the fact that geoengineering should not seem like such a stretch given humans, including Indigenous peoples, alter the environment as business as usual and to respond to environmental crises." Western scientists' misappropriation of "cherry-picking parts of Indigenous thought that appeal to them" (Todd, 2016: 18) exemplifies the ongoing epistemic violence within geoengineering discourses. Finally, supporters of SRM outdoor research advocate the urgent need to develop open-field trials for the benefit of vulnerable populations. These include – among others - millions of local and Indigenous people living in the Global South. Advocates of early SRM research such as Joshua Horton and David Keith "contend that a prima facie moral obligation exists to research SRM in the interest of developing countries because SRM appears to be the most effective and practicable option available to alleviate a range of near-term climate damages that are certain to hurt the global South most of all' (in Whyte, 2018: 295). Recalling the post-normal science framework, these authors suggest that reducing the dimension of uncertainty is in the best interest of the more vulnerable stakeholders and it is essential to avoid unjust outcomes of future SRM deployment. Yet, the 'decision-stakes' dimension remains unaddressed and moral and ethical nuances are subsumed into the Western 'normal' paradigm. Within these considerations, SRM supporters present the threatened socio-economic and ecological conditions of locals, Indigenous, and destitute as an urgent and pressing factor to encourage the immediate start of more robust research. In contrast, in the first and second examples provided by Whyte, Western scientists harness Indigeneity to reduce the 'decision-stake' dimension as they seek to explore the ethical implications of Indigenous acceptance for a variety of pro and anti-SRM positions.

Care

In the context of SRM governance, an area in which the Foucauldian notion of power/knowledge emerged is the way climate change and its solutions are framed and defined by scientists and researchers at large. Problem definition has a fundamental role in

guiding governance[9] and steering different sectors of society. The Carnegie Climate Governance (C2G) Initiative has been engaged in several problematic aspects of SRM governance through comprehensive reports (Felgenhauer et al., 2022), journal articles (Gupta et al., 2020), and online workshops (Ina Möller, 2020). The C2G Initiative seeks to catalyze the creation of effective regulations for climate-altering technologies, in particular for SRM and large-scale CDR, and it held deliberative workshops on a range of geoengineering technologies in the Global South (Táíwò and Talati, 2022) In an online lecture on the governance of stratospheric aerosol injection (2020), Ina Möller remarked on the importance of being aware of different framings of international issues as how a problem is defined influences how, when, and where is governed. This applies to public engagement as well as the framing of geoengineering influences people's perceptions[10]. The definition of climate change and its possible solutions are various, and they represent one of the core issues for effective governance as well as for equitable and unbiased engagement with the public. PES researchers have long been aware that deliberations sponsored by official authorities "might offer a shortcut to the public acceptance of new or controversial technologies" (Wynne, 2006, in Bellamy and Lezaun 2017: 411). Problem definition has important implications as different rationales of SRM research and deployment inform different regulation proposals. For instance, scholars are concerned that an 'emergency framing' of climate change may lead to undemocratic decision-making and the implementation of controversial technologies, such as SRM (Corner et al., 2011). Another example of competing definitions is provided by PES researcher Asayama (2015) who identified two opposing views of climate change. The first – "apocalyptic catastrophism" - portrays climate change as an existential threat where large-scale climatic interventions may be permissible to maintain existing laws, institutions, and social habits. The second view – "emancipatory catastrophism" - envisions a future where the threat of climate change can enable transformative shifts in societies, such as decolonization opportunities – also addressed by Gannon and Hulme (2018) – and therefore geoengineering is perceived as a futile and dangerous endeavor.

[9] Governance, in contrast to government, encompasses different approaches for the development, deployment, and assessment of global policy based on democratic coordination beyond voting for representatives, referendum, and civil disobedience. Governance relies on non-state authorities, such as non-governmental organizations (NGOs), private businesses, and stakeholder groups to create a coordinating framework and communicate with state agencies and representatives.

[10] See the section Preliminary Results for a thorough account of the issue of framing in SAI governance.

The different governance proposals engendered by these competing rationales have been the focus of a study on anticipatory governance[11] of SAI by Arti Gupta and other C2G colleagues (2020). Referencing Asayama's categories, they provided two opposing sets of governance proposals, either for enabling or restricting the future prospect of SAI. The first emphasizes "the need to foster an enabling research environment, with governance arrangements co-evolving with field tests that increase in scale and scope through time" (: 12). Research governance aims at identifying technical and environmental thresholds and ensuring transparency and accountability. Governance proposals associated with this perspective also seek to include developing countries and marginalized societal groups in the decision-making process as well as "ally a variety of concerns relating to potential future deployment of SAI." The second rationale informs governance proposals that aim at discouraging any kind of debate and research on SAI as it represents a moral hazard for the urgent task of emission abatement. In this view, tech fixes will only exacerbate existing structural inequalities. Research should be restricted if not banned – let alone future deployment. Governance actors should oppose research and demand legally binding international moratoria on outdoor experimentation. Finally, the seeds of societal transformativity should be cultivated in different ways, such as “through protest, deep societal transitions, or transfer of more power to the people” (: 14). In the final considerations of their empirical analysis, the C2G research group noted that “while our typology of rationales helps shed light on differences and similarities in governance proposals, it does not as yet fully unpack the confluence of factors that help explain these diverse visions and rationales themselves” (: 16).

These factors are the gaps that my thesis aims to address, and they include the different worldviews that rest on alternative ontologies, epistemologies, and values. They are elements that belong to the 'decision stakes' dimension of post-normal science. We can investigate the issue of problem definition in geoengineering through the “care approach”, proposed by Preston and Carr (2018) to assess the (un)justice of climate engineering with stratospheric aerosol. This method focuses on justice, but it does not narrowly look at the distribution of benefits and harms. The care approach goes beyond questions formulated within the scientific 'normal' paradigm and it looks for answers not only about the distribution of climatic benefits and burdens – such as reduced precipitation, cooler temperature, increasing amount of

[11] The term 'anticipatory governance' was first used in environmental policy studies in relation to novel technologies such as biotechnology or nanotechnology. It consists of “a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible” (Gupta et al., 2020: 11).

erythemal UV radiation, etc. – but also addresses politics and culture. For example, it includes historical circumstances that have disadvantaged certain groups, the requirement to carefully listen to marginalized voices, and the necessity of identifying the structural injustices that sustain subordination. This approach emphasizes relationships, context, dependence, power/vulnerability, affect, and narrative, areas that traditional assessments of political justice have tended to erase. The normativity of this approach is based on asking targeted questions about these neglected areas of concern[12]. The answers to these questions enable the researchers to better understand and articulate the local situatedness of a given problem. As with the ocean fertilization experiment, engaging the "situated belief and values" of those involved is a sine qua non for effective governance of SRM. This means attending to the specificity of the different visions of future climate and not merely addressing non-dominant views for heuristic purposes. "It is not enough to consider only the potential benefits and harms of climate engineering in terms of welfare" (Preston, Carr, 2018). Referring to a study of the C2G Initiative, Preston and Carr argued that an "expert-driven, outcome-oriented, and risk-based understanding of equity" does not address all the relevant issues of justice. In their insightful analysis, the authors call for a recognitional form of justice that would pay attention to neglected considerations. The care approach "proves itself to be particularly appropriate for identifying recognition and misrecognition" (: 312). It requires carefully listening to marginalized voices using "particular lenses deemed important by care ethics theorists." The care-based evaluation of public perceptions is "responsive to structural injustices and the ways that subordination can be institutionalized" (: 313). This approach scrutinizes policy proposals against the situation of vulnerable actors. Preston and Carr concluded that among policy-makers the care-based approach is not sufficiently considered and implemented. To detect all subtle forms of injustice that attend climate change, governance scholars are required to more effective frameworks not limited to benefits and risks considerations.

[12] The questions elicited by the care-based approach include among others: How might social and ecological *relationships* shift if this climate engineering strategy is introduced? What is the unique history, ecology, and culture (that is, the *context*) of this place? Where are the current relations of *dependence* in this situation and how might these change due to the use of this particular climate engineering technology? How does the development, deployment, and use of this technology affect the distribution of *power*? Does the development and use of SRM evoke strong *emotions* among those impacted? What are the narratives being told by those promoting and by those who will be subjected to SRM? What values and beliefs are being expressed in these different narratives? (Preston and Carr, 2018).

Governance challenges

The governance of SRM has been widely debated in several scholarly, policy, and media discourses. The Royal Society's seminal report concluded that "The greatest challenges to the successful deployment of geoengineering may be the social, ethical, legal and political issues associated with regulation, rather than scientific and technical issues" (Royal Society, 2009). Western as well as Asian scholars have advanced various possible governance mechanisms. A critical analysis of the governance literature on SRM exceeds the scope of my study. I will address some of the ethical concerns posed by geoengineering governance, but I will not examine the important role of non-state actors – notably, the IPCC, the operational decision-making, and the intellectual property associated with geoengineering. A notable methodological difference in this section is that non-dominant governance proposals will not be considered as a thorough analysis of such proposals exceeds the scope of the research[13]. Because of these limitations, this section is limited to an overview of the wide spectrum of challenges posed by solar geoengineering governance followed by a synthetic analysis of the governance instruments to address SRM.

The first problem is how to approach the technology itself as it entails a broad range of multiple risks across different segments of society. What kind of analytical framework could be used to comprehensively represent all the possible direct and ancillary impacts of SRM? The cost-benefit analysis would narrowly define climate benefits and financial costs of managing solar radiation, but countervailing risks and co-benefits and more importantly the situated beliefs and values of all relevant stakeholders might be left out of the decision framework (Felgenhauer, 2022). Another approach could be based on the precautionary principle. The international community adopted this ecological principle at the Earth Summit in Rio de Janeiro in 1992 and since then it has been used as an environmentally prudent basis for making policy decisions under deep uncertainty. It affirms that "if the environmental consequences of an action are uncertain then those actions should be avoided" (Bishop, 1997: 57). However, using the precautionary approach to enable SRM deployment may produce climate policies that focus on the target risks without considering potential side effects. On the other hand, if the precaution is against the risks of controversial technologies, the deployment would be discouraged without considering the potential benefits of climate risk

[13] For some examples of SRM governance conceived outside the Western academia see Parthasarathy (2010) and Whyte (2012). For an example of governance of technology based on Confucian ethics, see Tao et al. (2010).

reduction and other co-benefits in the decision framework (Felgenhauer et al., 2022). Moreover, the case of solar geoengineering is controversial because the application of the precautionary principle to pollution control measures is intended to treat a *symptom* of pollution but not its *cause*. Therefore, there is a fundamental difference in how the principle may be applied to the governance of SRM. Matthias Honegger and colleagues (2021) analyzed the potential implications of geoengineering for the 17 UN Sustainable Development Goals (SDGs). Their findings suggest that “Any successful deployment of SRM that achieves reduction of change across all key climate change variables is expected to reduce climate change impacts on attainment of all 17 SDGs" (: 21). However, the authors also concluded that countervailing impacts posed risks for the successful delivery of more than half of SDGs. Nevertheless, these outcome indicators are relevant, measurable, and collectively comprehensive and offer an assessment across a multitude of socially relevant parameters, rather than the single global air temperature. Moreover, SDGs were designed to be interconnected, and each policy option presents synergies and trade-offs (Truffert et al., 2020) that could represent appropriate criteria for assessing the political compromises involved in climate response management (Felgenhauer et al., 2022). Finally, a risk-risk framework has been proposed by the C2G Initiative for future SRM policy analysis and decision-making to enable a more comprehensive assessment, comparison, and management of risks associated with climate change, emissions reductions, adaptation, and geoengineering. This framework could also reference the SDGs and would address the full portfolio of important challenges, “identifying and weighing impacts on the target risks, countervailing risks, and co-benefits, recognizing that they may interrelate in complex ways” (Felgenhauer et al., 2022: 45).

Despite their heterogeneity, any governance framework confronts multiple challenges inherent to the properties of the technology itself. Law scholar Jesse Reynolds (2019) provided an overview of these challenges and identified four core issues of solar geoengineering governance. First, it would be difficult to properly govern the transboundary effects of large-scale outdoor activities because the international order lacks a global, centralized authority. Therefore, states will be the central actors and will "seek to retain decision-making authority over intentionally changing the climate" (: 6). Second, pursuing SRM as a policy option lacks incentives as it "threatens to divide the environmental political coalition that has been effective at advancing climate governance" (: 6-7). The deliberate and substantial intervention in nature implied in the use of SRM is in stark contrast with the core

belief of environmentalism and sustainability, which instead demand less human intervention. For this reason, until now, the state involvement with SRM governance has been limited, and "this seems unlikely to substantially change in the near future." Third, Reynolds argues that at this early stage, governance discussions on the use of SRM are to some degree speculative. Indeed, although there are still several unanswered technical and scientific questions, the most salient uncertainties seem political. Even if humans manage to control the climate, we do not know the future considerations of states on whether the same or divergent temperature and climatic conditions will be desired and how SRM will be prioritized relative to other objectives. This is why current governance discussions largely concern effective research rather than implementation. Fourth and last, the governance structure of SRM deployment is problematic, "although not as much as that of emissions abatement." The structural challenges that the two strategies posed are upside down. Abatement entails substantial financial costs for the single state that cuts its emissions, but it produces global net benefits. It is therefore in each actor's individual interest to 'free ride' by letting others contribute, i.e., the prisoner dilemma (Barret, 2024). In contrast, SRM deployment is low-cost[14] and could produce net benefits for a single state that undertakes it. It would be in each actor's individual interest to implement the technology and partake in the advantages of choosing the global thermostat. American economist Scott Barrett (2007) defines geoengineering as a single-best effort public good where one actor – the free driver - has the potential to determine the global temperature. Other countries, however, could disagree on when, where, and how to deploy SRM and - even worse - could be discouraged from pursuing serious emission reduction. In a game theoretic analysis of the impacts of SAI deployment on future global abatement levels, McEvoy et al. (2022) showed that non-cooperative abatement levels may increase or decrease under the threat of SAI, depending on how damaging the free-driver's level of deployment is on others. Assuming that countries' preferred level of SAI is a decreasing function of global emissions abatement, they showed that the individual state preference on the use of SAI is given by the difference between the optimal abatement level (Qo) and the actual abatement level (Q). Moreover, they found that the benefit function from SAI increases until deployment exceeds a country's preferred level. In this case, the difference between a country's marginal benefit of preferred deployment level and the marginal cost – given by the

[14] Different estimates are provided by different sources. Approximately, abatement financial costs are measured in annually USD trillions, while those of SAI deployment are measured in annually USD billions (Barrett, 2007; Parson and Keith, 2013).

difference between Q and Qo - is negative. These structural issues will have fundamental implications for International Environment Agreements that govern abatement. The stability of IEAs will be challenged by two competing strategic incentives: the well-known 'free rider' incentive and what the authors termed the 'anti-driver' incentive. The latter "is the benefit a country earns by joining an agreement and increasing abatement in order to motivate the free-driver to reduce its level of deployment" (: 1). The study concluded that if the anti-driver incentive is high enough, the threat of SAI "can expand both the depth (i.e., abatement level) and breadth (i.e., participation level) of stable IEAs" compared to a world without SAI.

Governance instruments

An oft-discussed topic regards the possibility of existing national and international regulations to be applied for the governance of SRM. Reynolds (2019) indicated some domestic environmental and liability laws in the United States that could provide an initial framework for state governance. These include the National Environmental Policy Act to assess the environmental impacts of SRM-related projects; the Clean Air Act to regulate sulfur dioxide and other pollutants injection in the atmosphere; and the Endangered Species Act to prohibit activities that would threaten critical habitats and vulnerable ecosystems. Besides domestic normative, scholars from the C2G Initiative (2020; 2022) proposed salient existing international treaties, conventions, and organizations where issues related to solar geoengineering could be potentially addressed. Treaties are a source of binding international law (Barrett, 2024) and they could be applied to govern the bio-physical risks of large-scale implementation of SRM (Reynolds, 2019), particularly SAI (Felgenhauer et al., 2022; Möller, 2020; Honegger et al., 2018;). These governance proposals, however, are based on the outputs of climate model simulations that are fraught with scientific and technical uncertainties. Besides the several unknown climatic and ecological responses to stratospheric aerosol enhancement, *deep uncertainty* also includes issues inherent to the ideal deployment of the technology, such as the choices of the optimal latitude and altitude (Wells et al, 2024), the temperature target (Keith and Dowlatabadi, 1992), the timing and duration (Aquila, 2014), and the baseline scenario (Wigley, 2006). The following existing regulations proposed by C2G and other scholars are meant to offset some of the scientific deep uncertainties that emerged during my analysis of the GeoMIP research on SAI based on climate model simulations.

The effect of sulfate aerosols on stratospheric ozone is one of the most critical uncertainties. Past measurements taken shortly after the eruption of Mount Pinatubo in 1991 registered a decrease of more than 6% in the tropical ozone column (Pitari et al., 2014). A thick cloud of sulfate aerosols could couple with chlorofluorocarbons (CFCs) and accelerate ozone loss cycles over the polar regions, increasing the amount of erythemal UV radiation that reaches the surface (Heckendorn et al., 2009). Researchers proposed that the governance for this particular side-effect of SAI could be regulated by the Montreal Protocol which already oversees states' emissions of ozone-depleting substances. Likewise, sulfur particle emissions could be regulated by the Convention on Long-Range Transboundary Air Pollution which limits industrialized countries 'emissions of acid rain precursors that drift across countries' borders. Sulfur dioxide (SO2) is a colorless gas naturally produced during volcanic eruptions or caused by anthropogenic activities. Long-term exposures are associated with an increased risk of adverse cardiopulmonary events, ischemic cerebrovascular events, and oxidative damage (Turner and Sapp, 2023). The negative impacts of SO2 on the natural environment could be addressed by the UN Convention on Biological Diversity (CBD) through the implementation of norms and codes of conduct that discourage approaches that affect biodiversity. Terrestrial biosphere responses to SAI have been scarcely taken into account by the GeoMIP. Some researchers (Xia et al, 2016; Gu et al, 2003; Govindasamy et al, 2002) examined the combination of aerosols' cooling effect and the enhancement of downward diffuse radiation, that is the reduction of direct radiation due to the aerosol scattering effect. These dynamics could increase plant photosynthesis and contribute to a higher carbon sink rate due to reduced plant and soil respiration during the geoengineering period. The enhanced photosynthesis in the tropics, however, is contrasted by the slow rate at higher latitudes (Gu et al., 2003) due to increased snow cover as well as by reduced soil water content at the regional scale and the global decrease of total direct radiation. To prevent any harmful impacts on the natural environment, in 2010, the CBD issued a resolution providing a few non-binding decisions on geoengineering. The deliberation has been referred to as a moratorium (Reynolds. 2019), but in fact, it calls for states to restrict “geoengineering activities that might affect biodiversity in the absence of an adequate scientific basis," therefore allowing some experimentation to go ahead (Pearce, 2010). For instance, the

resolution exempted small-scale scientific research studies and CDR projects that would meet four specific conditions[15].

Another relevant international agreement that could be used to prevent any kind of hostile use of SAI is the Environmental Modification Convention (ENMOD) which prohibits countries from modifying the environment for military purposes. Among the most critical uncertainties and moral implications of SAI, the disproportionate regional effects have been widely debated both by natural and social scientists (Robock, 2008; Hulme, 2014). Using volcanic eruptions as a proxy, regional variability seems to depend highly on the eruption site (Gu, 2003), therefore the latitude of SO2 injection will have important consequences for regional climate. Large aerosol clouds in the tropics produce changes in the atmospheric circulation, warming the winter period in the Northern Hemisphere (Aquila, 2014). At higher latitudes, instead, aerosols weaken the tropical monsoons, causing a reduction in precipitation and so in vegetational coverage in the monsoonal regions, as demonstrated by the famine in Africa, India, and Japan following the eight-month long eruption of the Laki fissure in Iceland in 1783-1784 (Robock, 2008). The risk of this knowledge being weaponized is real (Robock, in press) and the ENMOD Convention could provide an initial framework to prevent any hostile use of SAI.

Concerning the preservation of water bodies, the London Protocol regulates marine dumping, and it was recently amended by its 51 parties to include also "marine geoengineering," which could comprehend SAI (Reynolds, 2019). Sulfur particles may affect the El Niño Southern Oscillation (Gabriel and Robock, 2015), which in the past caused an increase in oceanic CO_2 emissions. Although simulated geoengineering climate modeling does not show any significant effect on El Niño, a protracted period of SO2 injections might impact ocean circulation (Gabriel and Robock, 2015). Regulation of the marine environment could also be governed by the UN Convention on the Law of the Sea which prevents any harmful effects on oceans and provides relevant obligations for states to protect the marine environment and their rights in conducting marine scientific research (Reynolds, 2019).

Finally, C2G researchers indicated the Paris Agreement as the main justification for the use of SAI (2020). The ambitious goal of limiting warming to two degrees above pre-industrial temperatures could be achieved through large-scale injections of sulfate aerosols in the

[15] Experiments (1) must be conducted in a controlled setting; (2) would not have impacts beyond national jurisdiction (in keeping with CBD Article 3) ; (3) are justified by the need to gather specific scientific data and (4) are subjected to thorough prior environmental impact assessment (ETC Group).

stratosphere. Reynolds suggests that states could incorporate solar geoengineering activities into their domestic climate strategy and their required adaptation plans. It could become part of the global stocktaking process required by Article 14 of the Agreement (Reynolds, 2019).

I believe it is important to emphasize that the theorization of these governance proposals is based on unknown and largely unknowable climatic responses. These knowledge gaps could only be narrowed by conducting more research in laboratories and also the open field. This position, however, takes us back to the ethical conundrum of SRM research illustrated by the post-normal science framework. The latter suggests that concerns of SRM go beyond the potential biophysical hazards of global deployment that an effective research program could potentially reduce. The moral issues associated with solar geoengineering research include "questions about the kind of world we want to live in that are broader than simply its climate" (Rayner, 2015). Having returned to the moral dilemma introduced in the initial part of the essay, we now turn to some final considerations of the features and challenges of the governance of SAI research for then moving forward to my methodological analysis of the PES literature.

Research governance of stratospheric aerosol injection

Governance discussions of stratospheric aerosol injection tend to separate research from deployment. This is because research is ongoing, regulated at the national, regional, or organizational level, based on consolidated scientific codes of conduct, and evaluated by ethical review boards (Möller, 2020). In contrast, deployment is a future possibility, it is subject to international laws and is not associated with any dedicated policy instrument. Moreover, deployment might be potentially hostile to other countries, whereas small-scale research would pose no significant international threats. This is a fundamental distinction that is not easily maintained in the course of public discussions (Bellamy et al., 2017). The research of SAI includes different activities depending on the 'location' and 'scale' of the experimentation. The location could be either indoor or outdoor. The first includes computer simulations and lab experiments. The second refers to open-field testing of devices or observation of how aerosols interact with the natural environment. The distinction between indoor and outdoor activities aims to address public concerns rather than avoid harmful environmental impacts as open-field small-scale experimentation would be much less intrusive than daily industrial pollution. The category of 'scale' generally applies to outdoor activities and distinguishes small-, medium-, and large-scale research. However, the

demarcation has not been formally delineated yet. This is one of the starkest critiques of the CBD's 2010 deliberation as it does not rule out the boundaries beyond which activities may not take place (Reynolds: 14). Parson and Keith (2013) urge to break the deadlock in geoengineering research by defining acceptable thresholds below which experimentation may proceed. They claimed that moratoria should not permanently ban SAI research as we might need it in the near future. They tentatively proposed a threshold measured by radiative forcing perturbation (ΔRF) for a global-annual average of $\Delta RF > \sim 10^{-2}$ Wm^{-2} where global climate response is barely detectable. Keith advocates for such contained experiments to go ahead, so as to avoid the risk of suppressing the study of technologies that offer large potential benefits.

In public engagement activities, the governance of SAI research is usually associated with five ideal-typical models (Bellamy et al., 2017):

- The negotiation of an international agreement to regulate and standardize the conduct of geoengineering research across countries (cf. Bodle et al., 2014, in Bellamy et al., 2017).
- The issuing of novel national laws or amendment of existing ones that prioritize unilateral state governance (cf. Merk et al., 2015).
- The establishment of a new independent body with the power to review and approve proposals for new research on SAI (cf. Rayner, 2015).
- Scientists' self-regulation, where research is overseen by scientists within the parameters of traditional peer review (cf. Parson and Keith, 2013).
- The enactment of an international moratorium banning any further research (cf. Hulme, 2014).

In a study presented at a geoengineering conference on ethics, climate scientist Jane Long (2015) argued that allowing these different governance strategies to be explored clarifies the intent of the research – whether indoor, outdoor, small-scale, or large-scale. She advanced five considerations that all research proposals should address: (1) conducting high-value research to generate a new understanding of the risks, effectiveness, and advisability of SAI; (2) researchers should evaluate their proposal's downsides, comparing impacts with those of other common activities; (3) conducting the experiments openly and in full transparency with the public is essential to maintain trust and ensure effective governance; (4) governance methods beyond normal peer review are needed to control the risk of bias evaluation due the

influence of financial interests and intellectual property rights; (5) the engagement with all the relevant stakeholders is a sine qua non for advancing research.

The importance of these considerations has been demonstrated by the failed project SCoPEX - Stratospheric Controlled Perturbation Experiment. Designed by the Harvard Keutsch group and financed by Bill Gates and other billionaires, this experiment represents the largest effort to date to collect data on the behavior of aerosols in the atmosphere to inform climate models of SAI (Paris, 2023). The experiment design and objectives were based on more than forty years of lab research and would have measured changes within the aerosol-perturbed air mass. The project was scheduled for June 2021 on Sámi domicile lands in Giron/Kiruna, northern Sweden, but days before the launch it was canceled. The Sámi Council sent an open letter co-signed by more than 30 Indigenous organizations from around the world to Harvard University demanding the annulment of the planned test flight (Risse, 2023). In the letter, the Council argued that representatives from the SCoPEX project never included Sámi people in the consultation process, as required by the UN Declaration on Rights of Indigenous Peoples (UNDRIP) and by the humanitarian principles of safeguarding those most vulnerable. Instead, Sámi learned about it from the Indigenous Environmental Network (IEN), which is part of the anti-geoengineering campaign Hands off Mother Earth (HOME). The Council's letter also raises further concerns toward the homogenous composition of the SCoPEX Advisory Committee, consisting almost entirely of US citizens (Risse, 2023). This precedent may represent a valuable benchmark for future experimentation regarding the importance of obtaining prior consent from all relevant stakeholders, including the most vulnerable and marginalized. It also demonstrated the significant leverage of Indigenous people in this matter. However, Oksanen observed that "By stating that SAI research should not be carried out in any ecosystem in the absence of global consensus, the Sámi Council might have overplayed their hand by setting an impossibly high bar that effectively amounts to outright rejection of SAI, which could lead to their exclusion from future discussion on its governance" (2023: 9-10). The SCoPEX case shows the potential for controversial technology to perpetuate and reinforce existing asymmetrical power relations. The approaches presented until now, that is the post-normal science framework (Rayner, 2015), the engagement with the situated belief and values (Gannon and Hulme, 2018), and the care-based approach (Preston and Carr, 2018), could offer a valuable framework for the governance of future outdoor experiments to seriously engage with the *things* that make up different worldviews through which other societies experience themselves and their relations.

This methodological framework should be based on specificity and obligations to break the academic bias based on epistemic violence. This would require including non-dominant thinkers who write in non-dominant languages and maintaining and respecting cultural distance without conflating different views.

The ripples of geoengineering in public perception

An overview of the PES literature

The literature on public engagement with science (PES) on geoengineering has been characterized by substantial changes since the first calls for public participation. The canonical report of the Royal Society (2009) provided a taxonomic distinction of various geoengineering proposals and "placed the overall discussion within a set of considerations that emphasized the governance challenges posed by this response to climate change" (Bellamy and Lezaun, 2017: 404). The report called for "an active and international programme of public and civil society dialogue … to identify and address concerns about potential environmental, social and economic impacts and unintended consequences" (Royal Society, 2009: xii). The Royal Society itself commissioned the first preliminary research conducted by the firm British Market Research Bureau that included four focus groups and a nationally representative telephone survey. Following this initiative, the UK Research Council immediately sponsored a series of public forums where different geoengineering options were tackled in formal debates. Preliminary results showed a generally negative perception of both carbon dioxide reduction and solar radiation management (Royal Society, 2009). A second round of public dialogue was held in the UK under the titled *Experiment Earth?* between February and May 2010. Funded by the Natural Environment Research Council (NERC) and designed by the social research firm Ipsos MORI, it was the "first major attempt at public engagement on geoengineering" (Corner et al., 2011). Participants were presented with the pros and cons of nine proposals – five CDR - biochar, liming the ocean, iron fertilization, air capture, and afforestation - and four SRM - stratospheric aerosol injection, space reflectors, white roofs, and cloud whitening - by rotating small groups around each technology. Facilitators struggled to present geoengineering in an unbiased and neutral way, seeking to overcome the "old-fashioned idea that public engagement is a one-way

process, rather than a dialogue between scientists and the public" (Corner et al., 2011: 7). The views expressed in the deliberative workshops indicated that "it was important to participants that geoengineering should not conflict with mitigation, and wherever possible should augment mitigation efforts" (Ipsos MORI, 2010: 2).

Following these pioneer enterprises, a substantial body of research deepened the understanding of public acceptance/refusal of different geoengineering proposals either through quantitative opinion surveys administered to a large number of people or qualitative deliberative workshops and interviews with a small number of individuals[16]. The scope of these studies was to gauge public perception of the moral, ethical, and societal implications of funding research into geoengineering (Low et al., 2024). These studies maintained the taxonomic distinction provided by the Royal Society as well as approached the issue through a similar methodology that mostly referenced the Western ethical framework (Sugiyama et al., 2020). Nevertheless, several common findings emerged from this literature: (1) PES researchers agree that public awareness of geoengineering is extremely low (Mercer et al., 2011; Merk et al., 2015; Asayama et al., 2017), however, it may vary upon the level of education (Visschers et al., 2017); recent studies confirmed the widespread unawareness among the public (Low et al., 2024, Baum et al., 2023). (2) mitigation remains the preferential choice in addressing climate warming (Bellamy et al., 2017); moreover, among the climate engineering proposals, carbon dioxide reduction is preferred over solar radiation management (Macnaghten and Szerszynski 2013); (3) the degree of acceptance of SRM research is always conditioned by mitigation efforts and presents many areas of ambiguity and ambivalence (Asayama et al., 2017; Bellamy et al., 2017); (4) the public generally supports international governance (Merk et al., 2015) (5) and the public response to the threat of the moral hazard is manifested in nuanced views (Corner and Pidgeon, 2014). For instance, results from the Royal Society and *Experiment Earth?* focus groups provided some tentative evidence that public opinion saw the prospect of geoengineering as a galvanizer of mitigation to demand action on greenhouse gas emissions reduction. However, Corner and Pidgeon (2014) noted that the argument of the moral hazard against geoengineering is likely to resonate with members of the public, but its persuasiveness is modulated by people's

[16] For public workshops analysis see *Parkhill and Pidgeon, 2011; Macnaghten and Szerszynski 2013, Amelung and Funke, 2013, Wibeck et al, 2013; Bellamy et al., 2017; Asayama et al., 2017*. For studies based on online surveys see *Pidgeon et al., 2010; Mercer et al., 2011; Bellamy and Hulme, 2011; Sugiyama et al., 2011, 2012, 2016; Bostrom et al., 2012; Corner and Pidgeon, 2014; Merk et al., 2015; Visscher et al., 2017*.

existing views about climate change. For instance, climate skeptics are less likely to be persuaded by the threat of mitigation deterrence.

As for stratospheric aerosol injection, public dialogue in the form of working groups or surveys was deemed critical to understanding citizen opinions about those areas characterized by *deep uncertainty* (Baum et al., 2024). Early studies scrutinized individual factors that positively correlate to the acceptability of SAI field trials. These include concern over the seriousness of global warming (Merk et al., 2015, Visschers et al., 2017); trust in governance institutions (Sugiyama and Fujiwara., 2016); and egoistic and non-altruistic values (Corner and Pidgeon, 2014). Moreover, the most recent research on SAI (Baum et al., 2024) represents one of the first-ever explorations of how public perception of risks, benefits, and overall support may be influenced by media-style reports. Researchers presented participants with news excerpts highlighting different factors related to SAI field trials, such as location, type of actor involved, and the scale and purpose of the efforts. They compared results from respondents in Mexico, the US, and the UK, reinforcing the idea that "publics in the Global South may be more supportive of solar geoengineering" (: 887). Their methodology and findings echoed Visschers et al. (2017) and, as the latter, Baum et al. too did not engage with local cultural specificities. As determinants of SAI support in Mexico, the authors tentatively indicated beliefs in a moral obligation to contribute to climate temperature mitigation and of science and technology as a solution. Finally, the familiarity with SAI among Mexicans[17] and their younger age might be supplementing factors to determine a more open-minded stance.

This generalization arose from the researchers' priorities yet neglected other ecological ontologies of local and Indigenous people. Professor Gregory Cajete encapsulated in the expression "Look to the mountains" one of the guiding principles of the relation between native Americans and the environment. The admonition reminds us "to think of the long-range impact on future generations when deciding what to do" (: 148) by attending to the "complex of relationship, symbolism, attitude, and way of interacting with the land." The active caretaking of nature is an ontological attitude shared by many Indigenous groups revealing that the environment is not understood as a passive object, but it is alive and dynamic (Ingold, 2000). Cajete defined this aspect of Indigenous ontologies as "Pueblo theology of the place" and it should be represented in the assessments of public perception of solar geoengineering in those countries that possess a wide and heterogenous subpopulation

[17] Derived by the illegal experiments of Make Sunset in 2022.

of Indigenous groups. It could be included in the care-based approach by engaging with specific questions that reflect the ontological view of the Pueblo theology of the place.

Re-framing geoengineering

The most salient feature of the evolution of the PES literature on geoengineering is what Bellamy and Lezaun (2017) defined as a process of *unframing*, that is the "deliberate effort on the part of PES researchers to expand discursive and analytic frames of reference" (: 403). This process was realized through the identification of some of the discursive lock-ins in early formulations of geoengineering that were quickly reversed and re-framed. In the initial activities in the UK, PES researchers noticed that the issue of intentionally altering the climate system to curb global warming was stabilized too quickly as a policy alternative, as a plan B for how to tackle climate change. The Royal Society report framed geoengineering as "a discrete and well-characterized object of deliberation" and called for a 10-year programme of research "on geoengineering and associated climate science" estimating an expenditure of £10 million per annum. Similarly, the IPCC's Fifth Assessment Report stated that "SRM methods, if realizable, have the potential to substantially offset a global temperature rise" (IPCC, 2014). This statement has been interpreted by the international community as a recognition of a theoretical 'Plan B' (Weng and Chen, 2014). Finally, in an article submitted to the National Academy of Energy Symposium in Washington (2002), Hungarian physicists Edward Teller et al. suggested that "active management of radiative forcing entails negligible – indeed, likely strongly negative – economic costs and environmental impacts, and thus best complies with the pertinent mandate of the UN Framework Convention on Climate Change. We propose that such approaches be swiftly evaluated in sub-scale in the course of an intensive international program" (: 1). In this context, "public deliberation could play an outsize role" and may serve to normalize geoengineering research "as both a matter of public debate and a suitable beneficiary of state support" (Bellamy and Lezaun, 2017). In this way, public deliberation processes can offer only token participation through information and consultation and as a result the public lacks significant influence over decision making. For geoengineering, this is even more problematic as public participation not only serve to legitimize it but also might have a performative role that makes appear the technology a real and viable option for contrasting climate warming even amid the deep scientific uncertainty of model simulations. In the words of one PES researcher interviewed by Bellamy and Lezaun:

The speed with which geoengineering has gone from being entirely speculative through the Royal Society report and the various research projects subsequently into something that is seen as very real – even though there is actually no additional knowledge on which to base that reification – is terrifying (: 411).

After these pilot activities, the second wave of public consultation sought to unframe such reification of geoengineering placing it within "a broader, looser range of matters of concern." After 2010, PES researcher analysis through working groups and surveys took a distinctive turn, portraying geoengineering not as a long list of pros and cons among different proposals but as a less discrete topic of engagement. This was achieved through the adoption of methodological innovations, such as the much less active role of the facilitators in workshops, and a pre-introduction to climate change and the causes of global warming to better situate the notion of geoengineering. In the second wave of public dialogue, the attention was steered to the conditions that had prompted interest in geoengineering in the first place, that is the increase in anthropogenic climate change and the political failure that hinders our ability to address its root causes.

The process of unframing has produced more nuanced and ambivalent opinions on geoengineering in deliberative workshops (Asayama et al., 2017; Bellamy et al., 2017) and surveys. Among the latter, three assessments conducted in the UK, the US, Canada, (Mercer et al., 2011), Japan (Sugiyama and Fujiwara, 2016), and Germany (Merk et al., 2015; Klaus et al., 2018) informed respondents on the pros and cons of SAI distinguishing between research and deployment. SAI research was framed as a possible response to an increase in global temperatures due to CO_2 emissions. Under this frame, these studies all similarly found that public acceptance of SAI and support for outdoor research were low. It is noteworthy that the long-term consequences of field trials were perceived as serious as the immediate impacts (Low et al., 2024). Among the main arguments for the refusal of SAI were the inability of aerosol injection to address increasing greenhouse gas emissions (Pidgeon et al. 2013) and SAI deployment to resolve global warming was perceived to be the easy way out (Merk et al., 2015). This research "indicates that public perceptions vary depending on the specific context" and contextualization of geoengineering (Merk et al., 2015). These studies also came upon the 'emergency framing' which raised public acceptance and resulted in more ambiguous views. Interestingly, they noticed that even under the 'emergency framing' support for more research did not necessarily entail supporting global deployment (Mercer et

al., 2011). Finally, participants were in favor of transparent governance of early-state research over moratoria or bans (Low et al., 2024).

A pressing concern related to framing SAI field trials that has not been explored even in the most recent PES research is the mismatch between public expectation and the capacity of preferred tests (Low et al. 2024). In SAI assessment, small-scale outdoor experimentation might improve our understanding of atmospheric chemistry and physics, but it cannot inform scientists about the biophysical impacts of global deployment. Therefore, assessing what research scale is deemed permissible by the public is highly controversial "given the planetary scope necessitated for impacts-testing" (Low et al., 2024). In my survey, this problem was addressed with question Q41 which asked what range and scales of field tests would be deemed permissible, if only large-scale experimentation – that is, global deployment – would answer our most salient concerns (Table 2).

The analytical understanding of this question by the public was challenging, and indeed it was left unaddressed by a consistent number of both Italian (30%) and Chinese respondents (20%). Chinese respondents seemed to express higher agreement on regional field trials (43%). This question highlights one of the salient features of SAI represented by the post-normal science framework where responses to human ignorance are divided into those who see it as a gap to be filled and those who believe it might be a guiding policy as geoengineering represents something incompatible with their worldview (Rayner, 2015). The quantitative results of my survey can offer only a limited assessment of the public perception of such a controversial issue. To better address the causes of the mismatch between public expectation and the capacity of preferred tests a qualitative analysis through working groups might yield more nuanced results.

The evolution of public engagement activities

In light of my critical analysis of the literature on public engagement with geoengineering, two underlying features were revealed (Table 1):

1. *The closing down of geoengineering proposals discussed during deliberative workshops and presented in online surveys*. Initial public engagement activities included the full spectrum of proposals, both CDR and SRM techniques. Subsequent public events and PES analysis, however, gradually narrowed the interest to solar radiation management techniques, particularly marine cloud brightening (MCB), and

sulfate aerosol injection (SAI). This gradual shift of the research focus may have been influenced by the broader political, academic, and popular debates born out of the Paul Crutzen consensus. Several media headlines portrayed SAI as a feasible, cheap, and fast-acting techno-fix (Bolsen et al., 2023). Such considerations along with continuous unsuccessful mitigation attempts have prompted the development of studies towards the manifold and multi-scale possible impacts of this technology, including scientific research and in-depth governance analysis. In contrast, sequestrating carbon dioxide requires substantial investments, and the climatic benefits of CDR are not to be felt for decades. Therefore, the international context and the scientific community may have stimulated a higher interest in SRM proposals, and among these specifically on stratospheric aerosol injection. Post-pandemic public exercises seemed to confirm this trend, as several PES researchers narrowed down the focus solely on SAI field trials (Baum et al., 2024) or compared SAI with other SRM proposals (Low et al., 2024) or included also other CDR techniques (Braum et al., 2023) but SAI remained arguably "the most visible of the options" (Low et al., 2024).

2. *The opening up of a more heterogeneous participation not limited to Western countries.* In the initial stage, public activities were mostly held in the UK and the US. Notable exceptions are represented by Sugiyama and Fujiwara (2016), Bostrom et al. (2012), and public events sponsored by the Solar Radiation Management Governance Initiative[18] (SRMGI) (2011). Most of the studies based on these seminal activities of public engagement maintained Western values as a reference and largely ignored local and marginalized perspectives. The importance of these views, however, was systematically (non)acknowledged in the conclusions, where researchers emphasized the need to broaden public consultation to all relevant stakeholders. Afterward, the situation changed, and several surveys were conducted by Western and non-Western scholars addressing a more heterogeneous public. In the course of making cross-cultural comparisons, however, these studies were still using the West as method (Sugiyama et al., 2020), framing the global issues of public perception of climate change and geoengineering in a dichotomic analysis between universalism and

[18] SRMGI is a civil society organization that supports capacity-building enterprises in vulnerable communities (Táíwò and Talati, 2021). SRMGI has sponsored several public events in non-Western countries that were not included in my analysis as these activities had a different participants composition mainly consisting of people from academia, civil society, and government. For some examples see the Consolidated Report of Three Workshops in Senegal, South Africa, and Ethiopia (2013) and an early assessment of Chinese public discourse on SRM (Edney and Symons, 2014).

particularism, between the West and the Rest. This includes using biased tools of comparative analysis such as arbitrary categories of the Global South against the Global North and rhetorics that respond to the Western research paradigm, providing answers for practical needs of the military, national defense, industrialization, third-world development, control of diseases, etc. Despite several calls for more engagement with non-Western stakeholders, Sugiyama et al. argue that "The current status of the literature is at odds with the widespread recognition that global conversations are needed to establish inclusive governance of SRM" (2020: 643). A wider geographical coverage is warranted as it could bring different cultural perspectives and “open up” the discursive space (Stirling 2008). Public exercises conducted after the COVID-19 pandemic substantially broaden their global reach, by including countries in every continent. Despite embracing a wide variety of cultural traditions, in both qualitative (Low et al., 2024) and quantitative (Baum et al., 2023) research, the link between public responses and the cultural view from which they originated was never brought to the fore. The inclusion of non-Western people seems to have a mere heuristic purpose that allows researchers to say: "Chinese chose this, Arabs chose that, and Nigerians also chose that.” However, the most relevant questions remained unaddressed. *Why*? What is the role of cultural background in modulating these responses? *How* do features of public perception entangle with the cultural views of different groups? *How* can we address such differences? *How* might cultural specificities pre-emptively determine public perception?

Table 1: Research on public engagement with geoengineering

Year	Title / Author(s)	Type of engagement activity	Countries represented	Geoengineering proposals discussed
2009	Royal Society	Deliberative workshops	UK	CDR & SRM
2009	Pidgeon et al.	Semi-structured interviews	UK	SAI & Space Reflectors
2010	Experiment Earth?	Deliberative workshops	UK	CDR & SRM

2010	Pidgeon et al.	National survey	UK	CDR & SRM
2010	US Government Accountability Office (GAO)	Survey		CDR & SRM
2011	SPICE deliberative workshops	Deliberative workshops	UK	SAI field trial
2011	Macnaghten and Szerszynski (2013)	Deliberative workshops	UK (Durham, London, Newcastle)	SRM
2011	Mercer et al.	Survey	UK, US, Canada	SRM
2011	Bellamy and Hulme	Survey + deliberative workshops	UK	CDR & SRM
2011	Amelung and Funke	Deliberative workshops	Germany	CDR & SRM
2011	Sugiyama et al.	Survey	Japan	SRM
2012	IAGP	Deliberative workshops	UK	CDR & SRM
2012	Deliberative Mapping	Deliberative workshops	UK	CDR & SRM
2012	Bostrom et al.	Survey	Austria, Bangladesh, Finland, Germany, Norway, US	CDR & SRM
2012	Sugiyama et al.	In-class survey	Japan	SRM
2013	Corner and Pidgeon	Survey	UK	CDR & SRM
2013	Wibeck et al.	Deliberative groups	Sweden	CDR & SRM

2014	Sugiyama et al.	In-class survey	Japan	SRM
2014	Visschers et al.	Survey	Canada, China, Germany, Switzerland, the UK, and the USA)	SRM
2014	Merk et al.	Survey	Germany	SRMs
2014	Australian and New Zealand Survey	Survey	Australian and New Zealand	CDR & SRM
2015	Kahan et al.	National survey	UK and US	CDR & SRM
2016	Sugiyama et al.	Survey	Japan, China, Korea, India, Australia, and the Philippines	SAI field trials
2016	Bellamy et al.	Deliberative workshop	UK	CDR & SRM
2016	Asayama et al.	Deliberative workshop	Japan	SAI field trials
2018	Klaus et al.	Survey	Germany	SAI
2018	Preston and Carr	Structured Interviews	Kenya, Solomon Islands, Alaska	SAI
2023	Baum et al.	Survey	Mexico; UK; US	SAI field trials
2023	Baum et al.	Survey	30 countries[19]	CDR & SRM
2024	Low et al.	Survey + focus groups	22 countries[20]	SRM (SAI, MCB, Space Reflectors)

[19] Nationally representative surveys of the public perceptions of climate-intervention technologies included 19 languages with at least 1000 participants for each country.
[20] Countries were divided into three groups: the global North (Australia, Austria, Germany, Switzerland, Poland, Spain, Italy, Norway, Sweden, the UK, and the US); the emerging South (South Africa, India, China, Indonesia, Chile, Brazil, Turkey, and Saudi Arabia); and the developing South (Kenya, Nigeria, and the Dominican Republic).

Specificity

The absence of alternative worldviews and ethical considerations outside the Euro-American framework are distinctive signs of how the topic of SRM has been incorporated into the literature of public engagement with science. Whyte laments that "geoengineering discourse, as it stands now, does not articulate ethics and justice issues in ways that are salient to Indigenous peoples as they grapple with today's climate change ordeal" (2018: 290). Public workshops and surveys conducted by PES scholars "are not even setup in the first place to make it possible for Indigenous peoples to express and have an audience for many of their concerns about risk, research, and power." Similarly, Confucian philosopher Pak-Hang Wong addresses the lack of intercultural exchange on the ethical issues raised by SRM. These issues are global in nature, but they are framed by PES researchers within the Western ethical traditions, "which presume particular normative standpoints and understandings of human-nature relationship" (2015: 28). Wong seeks to provincialize the Western view and explores the moral issues of SRM from a Confucian ethical perspective showing the contribution that diverse ethical considerations may bring about to the global debate on climate engineering[21].

Public perception assessment of SRM is afflicted by the endemic shortfall of non-Western representation, categorially defined as the *Global South*. Few studies have attempted to engage with alternative cultural views: Visschers et al. 2017, Preston and Carr 2019, Sugiyama et al. 2020, Baum et al. 2023, Low et al, 2024. Most of this research, however, considers the non-Western public as a single homogeneous entity, i.e., the *Global South*, missing the necessary intercultural exchange addressed by Wong when dealing with an issue that has a global identity and whose impacts will be instantiated disproportionally in different regions of the world[22]. The most recent wave of PES research aimed at filling the gap of

[21] Following the path traced before me by Indigenous and Confucian scholars, I attempt to unravel and defy some of the biases of geoengineering discourses by addressing the ongoing structural colonialism within the academy in order to ensure that marginalized voices are heard (Todd, 2016). To address such a systemic issue, I will resort to some examples of both Indigenous fights for and Confucian claims of self-determination. These examples may make more sense for some readers and less for others. I have a discrete experience with China and Chinese because of my work and my personal life choices. Therefore, when I take a Confucian perspective to explain a bias or cultural misappropriation, my personal standpoint and the reader's might differ. Nevertheless, I am strictly bound to my epistemic location as an Italian student, and I have no intent to conflate my experience with those of Indigenous and Confucian scholars. I wish to demonstrate my allyship as Liboiron suggested: *standing with a group without standing in their midst*, supporting the cause of cross-cultural discourse in the governance of SRM but understanding and acknowledging where I do belong and where I do not.

[22] As many Indigenous and Asian scholars pointed out (Todd, 2016; Liboiron, 2021; Whyte, 2018; Chakrabarty, 1992; Chen, 2010), the academic violence of silencing non-Western voices is a structural problem that pervades Western discipline and intellectual environment. The academy "currently claims to be striving for the worthy goal of 'ontological self-determination'" but it fails to create the conditions and provokes harm to those affected.

“how publics in the Global South perceive solar geoengineering” (Baum et al., 2024). However, relying on the West as a reference and adopting approximative categories such as ‘Global North’ and ‘Global South’ promote a research methodology that does not attend to *specificities* and *obligations*[23]. The knowledge gaps that these studies seek to address are the result of discussions often framed as a dichotomy: the East versus the West (Low et al., 2024), China versus the West (Visschers et al., 2017), Japan versus the West (Sugiyama, 2011), Bangladesh versus the West (Bostrom et al., 2011), Indigenous people versus the West (Whyte, 2018). In this way, Western values are implicitly assumed as a starting point of any public engagement activities (Chen, 2010). The research criteria that emerged from this framework are those deemed important by the Western perspective, such as economic growth and social progress, democratic governance, and the politics of the nation-state, while situated cultural values and beliefs may be neglected and erased.

Focusing *methodologically* on the specific relations between non-dominant worldviews and SRM means looking at nuanced connection and humility rather than substantiating uniqueness (Liboiron, 2021). The Indigenous cosmology and the Confucian philosophy present a vast account of the importance of specificity. Liboiron explains that even though in nature "everything is related […] this doesn't mean there is a cosmic similitude for relations. You are not obliged to all things in the same way" (: 24). Confucian ethicist Kam Por Yu provided an insightful account of the notion of harmony, a fundamental political ideal and a normative standard in Confucian thought. Harmony is an attitude that consists of “recognizing the values of different things and balancing one thing with another thing” (Yu, 2010: 16). This notion is a fundamental tenet of Confucianism, and it attends to specificity by not conflating humans and nature, balancing different options, and searching for mutual complementation of acceptance and rejection (Wong, 2015). The concept is better understood with the cooking analogy where various elements are involved and they need to be coordinated so that each fulfills its role(s), and "relates to other elements in an appropriate manner" without dominating them and resulting in an outcome always greater than the sum of its parts (Wong, 2015: 31). In other words, Confucianism is against assimilation and

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Attending to non-dominant standpoints genuinely and truthfully means "contending with the embodied expressions" of stories, norms, and thoughts that are bound within a cultural framework (Todd, 2016). This is to allow for the self-determination – ontological, physical, or otherwise – of non-dominant cultural traditions.

[23] I use the terms *specificity* and *obligation* methodologically as suggested by Liboiron. Both are employed to connote "situated differences that matter to political action" and not for mere academic categorization. These notions may represent a methodological instrument to address knowledge gaps in the public discourses of SRM.

sameness and in favor of harmonization and specificity, as noted in this passage of The Analects (*Lunyu*) 13.23:

君子和而不同，小人同而不和。

The sage harmonizes but does not assimilate, the petty man assimilates but does not harmonize.

As a case in point, Visschers et al. (2017) surveyed public perceptions of SRM in six countries: Canada, China, Germany, Switzerland, the UK, and the USA. The cross-cultural analysis largely resorted to economic and political considerations as well as theoretical standards conceived and developed in the West (Sugiyama et al., 2020), such as Mary Douglas's three cultural categories and the Hofstede cultural indexes. China is categorized as a country from the *Global South* against the others and it is interpreted in a dualistic frame where the results from the Chinese respondents are significant as they are opposed to those of respondents of other countries. This research takes the West as method, and it holds steady to the core beliefs of dominant science proposed by Professor Sandy Grande that serve as the basis for our Western common sense[24]. In the research findings, it was revealed that Chinese respondents had a more positive attitude towards the potential of SRM deployment and displayed lower concern on the issue of 'tempering with nature.' The authors noted that since China has "more experience with geoengineering" this may lead to a higher acceptance of SRM. 'China's experience' refers to the country's extensive cloud seeding programs. However, it may be argued that SRM is a Western creation and has been mostly tested on European and American soil therefore the explanation provided seems to be insufficient and vague. In the final remarks, the authors wondered whether "the outstanding perception of SRM is particular for China or whether it can also be found in countries with a similar economic and environmental situation" (: 541). Apart from economic considerations, an investigation of the different cultural standpoints from which such results might be derived is missing. As the example demonstrates, addressing the knowledge gaps of public perception of SRM does not simply require researchers to include people from the Global South in surveys and workshops, but a much deeper and tactical engagement is needed. In feminist STS literature, the concept of *response-ability*, that is "cultivating the capacity for response"

[24] Among these beliefs, those that my research aims to de-universalize are as follows: belief in the effective separateness of faith and reason; the subscription to ontological individualism; and belief in human beings as separate from and superior to the rest of nature (Liboiron: 16).

may reinforce the search for "more relational ethics and politics" that link SRM with different humans and non-humans (Liboiron: 17). By rejecting the West as method and looking at the Confucian ethical standpoint on geoengineering, we may gain a more nuanced explanation for the higher acceptance of SRM among Chinese respondents. Tu Weiming (in Wong, 2015), one of the leading scholars of contemporary Confucianism, describes Confucian environmental thought as an anthropocosmic philosophy in which humans and nature are not situated in two separate ontological realms. Although humanity and nature are one ontological entity – encapsulated in the expression 天人合一 *tianrenheyi*, only human beings have moral capacities, and therefore "nature is not considered to be intrinsically good or moral in Confucian thought" (Wong, 2015: 32). Since nature lacks moral capacities, when natural processes become unacceptable from a moral point of view, “humans’ intervention – even if large-scale – is not always morally impermissible.” However, as Wong goes on to explain, the moral permissibility of humans to act on natural processes “does not imply that all forms of human intervention are morally permissible, or that Confucian environmental philosophy warrants human exploitation of nature.” Cecilia Wee in her analysis of Mencius's thought on human-nature relation carefully distinguishes between “taming” and “plundering” nature, where the first means to “bring under one’s control as much of nature as is conducive to human well-being[25] (without thereby seeking to plunder and destroy needlessly the natural world)” (Wee 2009, in Wong, 2015: 33). Accordingly, the higher acceptance of SRM among Chinese respondents in Visschers et al. might be attributed to the moral permissibility of the traditional Confucian thought that may grant humans intervention in nature. The anthropocosmic view of Confucianism could and *should* be used as an instrument of analysis when gauging the perception of people living in Confucian societies. Merely addressing superficial, unspecific, and non-situated economic, political, and environmental considerations from a dominant, unquestioned, and unquestionable paradigm does not favor a genuine global dialogue on SRM.

The value of public participation

Western countries have different obligations towards climate change and the exclusion, or the instrumental inclusion, of non-Western views in governance processes may prolong the

[25] In Confucianism Human well-being is not understood as material welfare, but it is a morally loaded concept intimately connected to human virtues (Wong, 2015).

international inequities rooted in colonial subjugation and power inequalities (Whyte, 2018). As the SCoPEX project revealed, the governance of outdoor experimentation led by Western scientists and funded by Western institutions and private actors poses the risk of ignoring local, Indigenous, and marginalized perspectives. Research priorities and standards should be co-produced with all relevant stakeholders including technical experts, social scientists, civil society, and marginalized groups from all over the world in partnership with their counterparts in high-carbon-emitting nations. A code of conduct should be established and shared by researchers that promotes transparency and responsible research through independent committee oversight, and that "meaningfully engages a broad cross-section of civil society stakeholders" (Frumhoof and Stephens, 2017: 6). Understanding public perception of SRM must be an intercultural exchange (Wong, 2015), where researchers engage with the situated beliefs and values of different cultural perspectives (Gannon and Hulme, 2018) and consider the incongruences and incompatibilities with the Western view. Referencing Arnstein's ladder of citizen participation (Figure 3), it is noteworthy that the characteristics of stakeholder engagement processes can vary significantly, leading to different outcomes in terms of legitimacy (Arnstein, 1969).

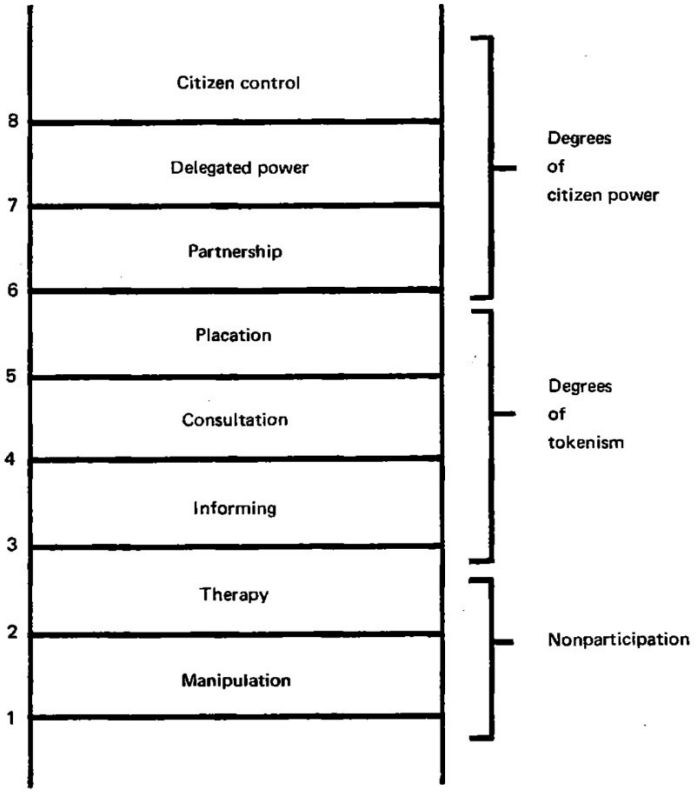


Figure 3: From Sherr R. Arnstein, *A Ladder of Citizen Participation* (1969)

Accordingly, participation can be an empty ritual where laypeople are not actively engaging or are offered token participation through information and consultation, or else it could be a meaningful activity where all relevant stakeholders are co-producers of the decision-making process and power is equitably distributed. The case of PES research into SRM is far from being an equitable and genuine global discussion (Frumhoof and Stephens, 2017; Sugiyama et al., 2020). The cultural nuances of the non-Western public are often subsumed into a more 'powerful' perspective, that is the views of the researchers, research funders, and field trial supporters. This results in engagement processes that reduce rather than strengthen legitimacy. Frumhoof and Stephens argued that public participation in the geoengineering debate should "provide opportunities for meaningful civil society input into research design and implementation, including, potentially, rejection or significant alteration of the proposed research" (2017: 8).

Although the role of public participation in decision-making is deemed fundamental in Europe, America, and other countries that share Western liberal democratic values, Wong (2013) argued that in Confucian societies public participation might be evaluated differently. For Wong, the Western tenets of *freedom* and *equality* are the central values that provide the moral foundation for public participation. Notably, these principles arise from a specific understanding of personhood. In liberal-democratic countries, a person is conceptualized as independent, rational, and self-determining. A person bears some fundamental rights that are shared equally by all with no distinction. In contrast, the Confucian notion of personhood summarized by Erika Yu and Ruiping Fan (2007) views persons as relational, developmental, and virtue-based beings. The three concepts are interdependent and essential to understanding the Confucian perspective on public participation with SRM.

Relationality is a central tenet in Confucianism distinct from Western philosophy as it is characterized by the emphasis it places on familial relationships that model all socio-political relationships. Family is the most fundamental social structure upon which all other social institutions are based. Social roles shape the notion of personhood in Confucian society because "to be a person is to stand in some relation to others appropriately" (Wong, 2013: 354). This notion is exemplified in the five basic types of human relations: parent-child, siblings, husband-wife, ruler-minister, and friendship. In short, a Confucian person cannot be identified independently without the relational and situated context in society, therefore "personhood *must* be ascribed via the roles a person occupies" (: 356).

To define the notion of personhood as developmental is to emphasize that personhood is not a fixed state. Accordingly, one can become a person by relating with others properly. Since the family represents the model of all social relations, being filial pious and fraternally reverent is the root of virtue-based development of the self (Yu and Fan, 2007: 174). Personhood needs to be understood, therefore, as an ongoing process. Persons are "neither static nor given." (Wong, 2013: 356) As Yu and Fan summarizes, a Confucian person is, therefore, someone who continuously seeks to develop their character and their moral virtues. As a consequence, not all people are conferred the same level of personhood and the same moral status. One famous Confucius quote says “men are close to one another by nature. They drift apart through behavior that is constantly repeated” (Yu and Fan: 176). As individuals progress beyond the early stages of life, personhood must be proved at different degrees through the practice of *li* – rites – and the extension of benevolence – *ren* - from the family to larger social circles.

The concepts of ‘rites’ and ‘benevolence’ are central to the third and last feature of the Confucian notion of personhood. The rites – or rituals – are to be understood as "behavioral patterns that embody the accumulated insights of the ancient sages" (Yu and Fan, 2007: 174). They are a social institution that is fundamental not only for achieving a harmonious society but also for the development of the personal character, that is of moral virtues. They prescribe what are the duties and obligations of specific social roles. The cultivation of virtues within a web of social relationships is at the center of the Confucian notion of personhood (Wong, 2013). Since the concept of personhood is not static in Confucianism, individuals are required to “continuously prove that they are ‘worthy’ of the status by appropriately cultivating their character at each stage of their life” (Yu and Fan, 2007: 175). *Ren* – benevolence - is a cardinal virtue that embodies “both Confucian concepts of humanity and the character of the Confucian ideal person” (: 173). One manifestation of *ren* is love between members of the family. If this sentiment is reciprocated, one can expand it to other social relations and embrace those who are more distant.

Wong (2013) argued that this alternative conceptualization of the person undermines the moral foundation for public participation in the governance of SRM. The implication of different responsibilities that arise and are prescribed by different social roles is that inequality in decision-making is a desired socio-political condition “because individuals’ degree of virtuousness and virtuous capacity vary” (: 359). The virtue-based notion of personhood entails that individuals are not equal and the views of the virtuous and capable

person weigh more in the decision-making process. The Confucian notion of personhood entails a different understanding of the role of public participation and it constitutes a serious challenge to the normative rationales highlighted by Frumhoof and Stephens (2017). Wong aptly concluded that “if public participation is morally important in geoengineering governance and the ethics of geoengineering, then it must be grounded on values that are *locally* rooted and can thereby be recognized and accepted by ethical-political traditions different from the liberal-democratic tradition” (: 360).

Harmony

A distinguished number of studies have sought to organize and define the notion of public acceptability of geoengineering research (Bellamy et al., 2017), particularly of SAI field trials (Merk et al., 2025, Sugiyama et al., 2016; Asayama et al., 2017, Sugiyama et al., 2020; Baum et al., 2024). The results from these studies show that acceptability presents many areas of conceptual ambiguity as it is often made up of fluid categories subject to different interpretations. For instance, considerations about the ‘location’ and ‘scale’ of the experiment influence significantly the public view on the most appropriate governance mechanism. Yet, these factors are not independent, but their meaning is shaped by reference to additional elements. An indoor, small-scale experiment may be deemed unacceptable if it is thought to be implemented unilaterally by a rogue actor. In contrast, a large-scale field experiment may be supported if it is believed to be an international concerted response to a climate emergency. Both natural and social scientists unanimously agree that the ‘emergency framing’ is problematic, not only because a ‘climate emergency’ is scientifically indeterminable (Corner et al., 2011) but also because such framing itself is indeed politically dangerous, pre-emptively closing down democratic debate (Stirling, 2008). PES researchers are well aware that this kind of problem definition creates a biased condition that may force people to accept the argument of more research (Corner et al., 2011; Asayama et al., 2017). Nevertheless, this framing is still used to discuss geoengineering research (Low et al., 2024) and to advocate in support of SAI field trials (Parson and Keith, 2013).

Amid this literature, British and Japanese PES researchers Rob Bellamy and Shinichiro Asayama particularly focused on the ambiguities and ambivalences that produce, modulate, and define public acceptance of geoengineering research. In 2016, a deliberative workshop held at the University of Tokyo specifically addressed the public acceptability of SAI field trials. After presenting the socio-ecological risks of sulfate aerosol outdoor research, "the

virtual consensus of participants on the more research argument" generated by the climate emergency framing "was disrupted into far more ambiguous and ambivalent views" (Asayama et al., 2017: 90). Japanese PES researchers described the public perception of SAI field trials as characterized by a profound "multivalence" and "ambivalence". The former includes the "visible clashes of different worldviews" of solar geoengineering experimentation; the latter refers to people's hesitation "about having one's own decisive normative position on geoengineering experimentation when faced with diverse conceptions of it" (: 90). Similarly, British PES researchers (2017) analyzed the results from three workshops held in the UK in the same year that explored public attitudes of different research proposals. The authors proposed that fluid notions such as 'scale' and 'location' may be understood as proxies to measure the degree of controllability attributed to any given geoengineering experiment. Both studies concluded that the public acceptability of geoengineering research requires a multidimensional approach. Asayama et al. indicated four interdependent dimensions – accountability, controllability, predictability, and desirability – that modulate public acceptance. For instance, concerns over uncertain risks pertaining to SAI field trials (predictability) are related to mistrust of scientists (accountability) as well as anxieties over the irreparable damage of outdoor research (controllability). In contrast, British researchers suggested that controllability is the main rationale of public acceptance, and it is composed of four interrelated dimensions – spatial containment of the experiment, risks and uncertainties, reversibility of ecological impacts, and scientific purity, that is research conducted by reliable actors with no commercial intent.

It is noteworthy that the participant composition and the conclusion of both research present several analogous features. In the Japanese focus groups, thirty-six participants living in the Greater Tokyo area were recruited by a professional consulting firm. The sampling of participants was designed to cover a diverse range of perspectives but also to be internally homogeneous within each group, "to foster a favorable atmosphere for group discussion." In the UK, twenty-one participants were recruited among the citizens of Norwich and divided into three groups corresponding to the three cultural archetypes developed by Mary Douglas and Aaron Wildavsky (1982), distinguishing a majoritarian, an egalitarian, and a hierarchical focus group. Although these studies were conducted in opposite corners of the Eurasian continent, participants possessed a similar societal background coming from Norwich and the Greater Tokyo area, respectively among the top 22% and 33% of the most expensive cities in the world (Livingcost.org). This issue has been acknowledged in some recent studies

(Sugiyama et al., 2020, Baum et al., 2023) suggesting that research on public perception of climate change and geoengineering is generally caught in Western bias because it relies mostly on the populations from WEIRD (Western, educated, industrialized, rich and democratic) countries. Finally, both research similarly concluded that the dimensions that made up the acceptance of SAI field trials have manifold inter-relations that lead to ambivalent, highly qualified assessments of certain forms of research. These findings originated from a similar methodological approach that uses the West as method, indicated by the citational choice of the authors that included only Western scholars with few exceptions. Japanese researchers did mention Confucians' theorization of geoengineering and tentatively indicated the incongruences of some of the issues highlighted in the dominant PES literature. However, these references remain aside as an addendum to the central research methodology and were never really used to broaden the ethical discussion on geoengineering research.

This may reflect the structural issue of the dominance of Western-centrism as a framework of desire and knowledge, a structure that is difficult to shake loose (Chen, 2010: 222). Referencing the Confucian tenets of harmony may allow us to enrich the discussion on the acceptability of SAI field trials. The concept of harmony has been often neglected in Western political thought because the primary concern of Western politics is the resolution of social conflicts and the protection of individual rights (Tao et al., 2010). In contrast, to several East Asian governments harmony symbolizes an ancient and profound theme that still shapes their domestic policy. Harmony may be understood as a normative and organizing concept that can help to promote new thinking in governance (Tao et al., 2010). In Confucianism, harmony is the ideal relationship between human beings and Heaven, that is, it constitutes a normative standard within an individual and between individuals that is instantiated at different levels: family, society, and the world. Chengyang Li emphasized that "the harmony-disharmony distinction has a role similar to distinctions of right-wrong, good-bad, and success-failure" (Wong, 2012: 72). In his insightful analysis of the notion, Kam Por Yu explained that "harmony is a valued-loaded term, which may mean different things to different people" (: 15). The author summarized four key features of harmony in Confucian thought: (1) harmony is not complete agreement; (2) harmony is balancing one thing with another one; (3) harmony is not unprincipled compromise; (4) harmony is the mutual complementation of acceptance and rejection. I have already discussed the first two normative implications of the harmonious approach that demand specificities and obligations. Similarly, the differentiation of harmony from unprincipled compromise remarks the need of every person to attend to one’s proper

roles and functions. An unprincipled, unreasonable compromise “is detrimental to harmony.” The notion of mutual complementation of acceptance and rejection refers to the idea that harmony “is achieved only if we are able to appropriate what is acceptable in what is objectionable and denounce what is objectionable in what is acceptable” (Yu, 2010: 23). In other words, the complexity of reality is such that absolute state of acceptance and rejection is doubtful, and it entails a pragmatic vision of the concrete situation, in which particularities become salient. Since concrete situations are not fixed nor absolute, harmony is better understood as “continuous negotiation and adjustment,” as a process – i.e., harmonization – to call for “the optimization *of* and *in* concrete situation” (Wong, 2015: 32). In outlining the possibility of using harmony as a guiding principle in the ethics of technology, Wong (2012) argued that in Confucian thought, harmony/harmonization "does not seek a final answer" since it demands continuous compromise, and therefore ethical issues will be formulated differently. Wong reflected that Western ethical theories distinguish between right and wrong based on a narrow focus on norms and moral principles. In contrast, he argued that Confucian ethics of technology based on the notion of harmony "will be formulated in terms of know-how, focusing on learning and practicing harmonization in the technological world" (: 81). The theorization of Confucian ethics on technology is "justifiably" vague and ambivalent. Since ethical decisions are understood by Confucians as continuous processes of self-development, inquiries will not be formulated in the form of discrete and discernible issues in ethics and technology. In conclusion, the permissibility of human intervention in the climate is granted as long as it abides by the normative standard of harmonization, that is, it should “enable people to fulfill their role(s), to relate to nature in an appropriate manner, and not do dominate it.” Accordingly, Wong concludes that acceptance of SRM research among Confucians will be in favor of those climate engineering strategies that complement and support the climate system, and against those that attempt to replace it.

Analytic Survey on the Public Perception of Stratospheric Aerosol Injection

Survey design

The survey builds on earlier studies (Merk et al., 2015; Sugiyama and Fujiwara, 2016; Sugiyama et al. 2016, 2020; Baum et al, 2023; Baum et al, 2024), however, digs deeper into

the incompatibilities between the Western and the Confucian views by comparing the perception of Italian and Chinese respondents on the role of public participation in the governance of SAI field trials and their attitudes towards the environment, knowledge, and technology. Notably, I refer to SAI open-field experimentation because the current debate around the governance of albedo modification technology is focused more on research, especially outdoor field experiments, than on deployment (Sugiyama et al., 2020).

The surveys were conducted via a web-based, commercial service provided by SurveyMonkey, an experience management company based in San Matteo, California. The survey panel is maintained and provided by the firm and its partners. I first designed the survey in Italian and then translated it into Chinese. The project also includes a video presentation on the risks and benefits of SAI outdoor research realized with Filmora, a timeline-based video editing software powered by the private company Wondershare. Respondents were recruited for a survey on perception of climate warming and its possible solutions and were told their responses would be anonymized, and that it would have taken about 10 to 15 minutes to answer all questions. The survey responses were collected from 17 December 2024 to 30 January 2025. The answers have been assigned a four-point Likert scale and when it was appropriate, I aggregated responses into two categories of agreement and disagreement by combining the responses 'totally agree' with 'somewhat agree' and 'totally disagree' with 'somewhat disagree.'

The comparison between Chinese and Italian respondents has been conducted in light of the findings of the most recent PES literature and the analysis of Confucian scholars (Pak-Hang Wong, 2013;2015; Erika Yu, Ruiping Fan, 2007; Erine M. Cline, 2014; Kam Por Yu, 2010). Following Bostrom et al. (2012), and Sugiyama et al. (2020) students were chosen to approach people with a similar educational background across Italy and China and to enable a sensible cross-country comparison in my survey sample. As noted by Lee et al. (2015) education level is "the single strongest predictor of climate change awareness" and it directly affects the public perception of climate modification technology (in Sugiyama et al., 2020: 644). The survey sample consisted of 100 Italian and 100 Chinese students; in both groups, there was a slight majority of female respondents. Most of the respondents (89%) in the Chinese sample were aged between 16 to 34 years, while Italians were more distributed with 70% aged between 16 to 50 years. The majority of respondents in both groups had completed or were undergoing a bachelor's degree (China: 90%; Italy: 80%). Nearly all the Chinese respondents (97%) were urban residents while in the Italian sample, this prevalence was less

pronounced (78%). Finally, a considerable limitation of the survey is that although respondents from both groups were students, in the Chinese group design, architecture, and music were the most common faculties, while in the Italian group majors in environmental science were prevalent. The higher awareness of climate change among students of environmental science has been indicated as a potential bias for surveys on geoengineering (Sugiyama et al., 2020). Despite this limitation, the main objective of my work was to gauge the perception of the Western public against non-Western ontological and epistemological views. Therefore, the different academic backgrounds of Italian and Chinese respondents did not jeopardize the fulfillment of my broader intent.

Survey instrument

The survey comprises 50 questions divided into three main parts: (1) opinion on climate change, (2) opinion on SAI and SAI field trials, and (3) personal information. The survey instruments include the following:

- One preliminary question (Q1) about respondents 'attitude towards risk, measured with Dohmen et al.'s (2011) scale of values, ranging from 0 ('risk aversion') to 10 ('risk propensity'), as in Merk et al (2015).
- Five questions (Q2-Q6) on attitudes toward global warming, based on Mercer et al. (2011); Merk et al. (2015); and Sugiyama et al. (2020).
- Five statements (Q7-Q11) on the ecological attitudes and human-nature relation, based on three items of the New Ecological Paradigm Scale (NEP), and the Confucian ontology (Wong, 2012, 2013, 2015).
- One question (Q12) on trust in institutions, based on Sugiyama et al. (2016), that further contains five subquestions. Among these, Q17 represents the only difference between the two surveys, presenting two different institutions (China: ASEAN; Italy: European Union).
- Five questions (Q19-Q23) on ontological and epistemological attitudes, based on Confucian notions of personhood, harmony, self-cultivation of virtues, and the doctrine of the mean – *zhongyong*.
- Background video on SAI (available at https://www.youtube.com/watch?v=181TVoOUz9E).
- Ten questions (Q24-Q33) on attitudes towards SAI, based on Merk et al (2015). Notably, two questions (Q32-Q33) focused on SAI field trials.

- Eleven questions (Q34-Q44) on the importance of public participation for the governance of SAI field trials, based on the incompatibilities I reviewed between the dominant and Confucian literature on geoengineering, for example, the different perspectives of personhood.
- Seven questions (Q45-Q51) about personal information, notably gender, age, education level, domicile (urban/rural), and academic field.

Preliminary results

Through two critical early analyses (Corner et al, 2011; Bellamy et al., 2012), followed by many others (Bellamy and Lezaun, 2017; Frumhoof and Stephens, 2017; Aldy et al., 2021), several problematic areas of public dialogues on geoengineering emerged. These concerns are related to the way climate modification technologies were framed and described by PES researchers, including the 'emergency framing;' the use of visual materials; the 'naturalness framing;' and the use of languages and translation, among others. In the following, I will present the most salient problems and discuss the approach adopted in my survey.

Presentation sequence

I have already mentioned that one of the methodological innovations adopted in the second wave of PES research was the introductory contextualization of climate change and the political failure to address the issue. Another relevant dialogic shortcoming of initial activities was that moral and ethical considerations of funding geoengineering research were presented after the explanation of the pros and cons of different CDR and SRM techniques. This order of presentation may have discouraged the public from fully expressing its opinion about the concept of geoengineering *vis a vis* other solutions and in the broader context of climate change (Corner et al., 2011). Following the most recent literature, the video presentation included in my survey starts with a quick prelude to the issue of global warming caused by fossil fuel-based economic development. Before the introduction of SAI, the recording emphasized that to alleviate the effects of global warming, industrialized countries need to reduce CO_2 emissions, seeking alternative energy sources. Subsequently, a non-technical explanation through visual material is provided about the benefit of global cooling and the main side-effect of uncertain regional impacts. Finally, the video discusses the argument of SAI field trials presenting both perspectives of supporters and opponents of outdoor research.

Emergency framing

I have already discussed the implications of using the notion of a 'climate emergency' or 'climate catastrophe' to present geoengineering. The definition of ‘dangerous’ climate change is controversial, and it is instantiated differently in different parts of the world. Many Arctic Indigenous groups have already declared a climatic emergency as their habitat is melting away; Pacific Islands will vanish under constant sea level rise; and Africans and Australians are suffering the most from intensified heat and drought (Lovelock, in press). Although the modern idea of geoengineering arises from the concern of the steady increase in greenhouse gas emissions, presenting SAI as a possible response to a climate emergency is problematic because it creates a strong framing of necessity to conduct research in the early stage and increases the ambivalence of public opinion (Corner et al., 2011). I avoided completely such framing in the video presentation, but I included one question (Q28) aimed at gauging public responses under the climatic catastrophe scenario.

Responses revealed that both Italian and Chinese students support SAI deployment under the emergency framing (Table 2). Interestingly, Italian respondents exhibited a higher internal conflict derived from the influence of the emergency framing. Under a neutral framing (Q26), the majority (77%) expressed disagreement with SAI deployment, but nearly the same percentage agreed that SAI should be used to prevent a climate catastrophe. The Chinese group similarly exhibited greater support for SAI deployment under the ‘emergency framing’ but it also shows greater consistency for the general support for SAI deployment echoing previous findings (Visschers et al., 2017; Baum et al., 2023; Low et al., 2024).

Visual materials

Early public engagement exercises abundantly used visual materials to depict geoengineering technologies. These images conveyed meanings and impressions that were not directly related to the physical appearance of the technology. For instance, illustrations in *Experiment Earth?* connoted a sense of daily life and normality by presenting small-size air capture fans almost seamlessly integrated into the urban landscape (Corner et al., 2011). Such presentation poses a biased condition for the public evaluation of geoengineering by making appear theoretical and untested technologies as a reality. More recent research carefully selected visual materials and emphasized that are "artist's impressions" of fictional technologies (Bellamy and Lezaun, 2017).

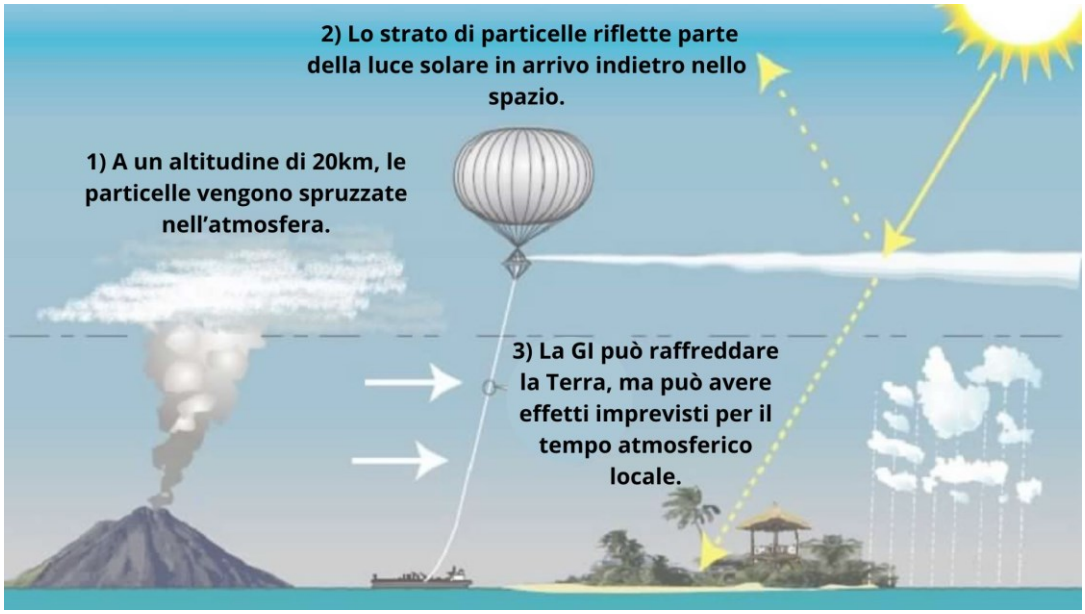


Figure 4: Image from the video presentation.

My video presentation resorts to an illustration realized for the SPICE project that I slightly modified to introduce a three-step explanation of SAI, based on the sample provided by Sugiyama et al. (2016). The picture straightforwardly presents the functioning of SAI by showing an air balloon releasing sulfate particles in the sky. The image implies an analogy with volcanic activities and this is a shortcoming that may make appear SAI as resembling a natural process. Finally, the picture also hints at the uncertain effects at the regional scale, particularly those related to the hydrological system, by showing a tropical island surmounted by rain clouds.

Language and translation

The choice of words and expressions through which SAI is presented is an important issue for how public discourse is framed. In the first wave of public activities, climate change, and geoengineering were presented by employing several technical terms as well as technical graphs and figures. In this way, participants struggled to understand the complexities of climate science and the proposed technologies (Corner et al., 2011). Moreover, different geoengineering strategies were initially presented as 'techniques' while subsequent studies referred to them as 'proposals' to emphasize their theoretical dimension (Bellamy and Lezaun, 2017). In the second wave of public groups and surveys, terms such as 'parts per million,' 'sulfate,' 'stratosphere,' and too technical graphs and explanations were removed to the benefit of public deliberations that were more focused on the social values and cultural worldviews rather than on the technical risks and benefits. Moreover, the appropriateness of

the term geoengineering itself is at the center of an ongoing debate among natural and social scientists (Merk, 2015). Many claim that it is ineffective as is "strongly confounded with geotechnical engineering and environmental engineering, rather than an intervention into the earth's climate system" (Mercer et al., 2011: 8). The ethical implications of this technology may not be encapsulated by the term 'geoengineering,' and this poses a biased condition for public understanding. Proposed alternatives include 'solar radiation management', 'climate remediation', 'climate intervention', and 'albedo modification' (Sugiyama and Fujiwara, 2016). Mercer et al. (2011) suggested that terms such as 'climate engineering' might be more appropriate as it captures the essential aspect of the technology. Another potential bias derived from the linguistic framing is the emphasis put by researchers on the cooling effect of sulfate aerosols that could promote a business-as-usual approach (Corner et al., 2011). This framing obfuscates the real reason why we need to reduce global temperatures and hides the potential side effects of SAI and its hollowness towards other pressing matters, such as ocean acidification and air pollution. Similarly, if SAI is presented as a solution to the failure of international cooperation to abate CO_2 emissions, the governance of the technology could be misinterpreted as less problematic, and the implementation of an SAI project may be perceived as more straightforward than mitigation or adaptation plans. Although the governance of SAI has been assessed as "less problematic" than that of abatement (Reynolds, 2019), we have seen how large-scale deployment would certainly require significant political will and public support as any other climate policy option would do.

In Italian, climate modification technologies are usually termed '*geoingegneria*,' and in my survey, I abide by this common expression. To address the issue of technicalities that would have distracted respondents from the more important moral and ethical considerations, I used the two letters "GI," a made-up abbreviation for *geoingegneria*, to refer to SAI, without mentioning the words 'sulfur,' 'sulfate,' 'stratosphere,' and 'aerosols,' that are usually linked with albedo modification technologies.

Finally, outside the Euro-American academy, an oft-debated issue is how the word 'geoengineering' has been translated into different languages. In Japanese and Chinese, the term has been initially rendered with 'earth engineering' – *chikyu kogaku* and *diqiu gongcheng*, respectively (Royal Society, 2009). This terminology is problematic because has a similar connotation to civil engineering and does not address the controversial implications of climate modification technologies. My Chinese translation follows the one provided by Sugiyama and Fujiwara (2016). I employ the term *qihou gongcheng* – climate engineering –

that better represents the notion of climate modification technology. Sugiyama (2020) argues that so far little attention has been paid to the global implications of these vocabularies and their informative potential in different languages. The Japanese researcher hopes that future discussions will be more mindful of the linguistic aspects in non-English societies.

Naturalness

A recurrent bias of early PES research was framing geoengineering as a technology that would simply scale up natural processes (Corner et al., 2011). Most of the literature analyzed suggests that perceived naturalness is an important factor in determining public attitudes toward geoengineering technologies (Pidgeon et al., 2012) and it is likely to raise public acceptance (Asayama et al., 2017). Analogies with natural processes include for example the description of chemical vents for capturing carbon dioxide from the air as 'artificial trees', or 'volcanic activity' to picture the release of sulfur particles into the stratosphere. British psychologist Adam Corner suggests that "although these characteristics might be technically accurate, they also provide a powerful framing: that the way to think about these technologies is by analogy to existing 'natural' processes" (2011: 21). This interpretative frame could be further emphasized in working groups where the engagement with the facilitators is direct and people could be led (intentionally or otherwise) to identify geoengineering as being 'natural.' Consider the statement of one participant in *Experiment Earth?*

"I had concerns that sulfate particles were not very natural…but the scientists explained to us that obviously they were natural, and with the association with the volcano recently, they explained it was the same sort of thing and that there were particles even in this room" (Female participant in Event 3 of Experiment Earth? Corner et al., 2011).

It is noteworthy that the recent volcano the participant referred to was the Eyjafjallajokull eruption that was taking place at that time. The erupting activity in Iceland caused a severe disruption to aviation across Northern Europe. It could be argued, therefore, that the reference to a volcano would have produced negative feelings for participants in their evaluation of SAI but research findings suggest that through analogies with natural processes, the technology was perceived more positively. The 'naturalness framing' intersects with the wider issue of ascribing meaning to nature that is likely to have an influence – either positive or negative – on public perception (Swyngedouw, 2011). In his conclusion, Corner argued that the public concern about naturalness could represent a more profound expression of anxieties about the

negative environmental impacts caused by the industrial age and “it may, in fact, be reflecting a deeper question about whether geoengineering is sustainable (in the broadest sense)” (: 22).

Following this literature, my survey presents one question (Q29) aimed to gauge whether the perceived naturalness of sulfate particles would influence the public attitude toward SAI. Contrary to expectations, the results displayed a strong majority of disagreement with SAI deployment under the ‘naturalness framing’ in both groups. Among the Italian respondents, framing SAI as a natural process did not produce any significant difference in terms of acceptance. Surprisingly, in the Chinese group, the ‘natural framing’ did not evoke positive attitudes but, in fact, it lowered acceptance among respondents by nearly half compared with Q26 (Table 2).

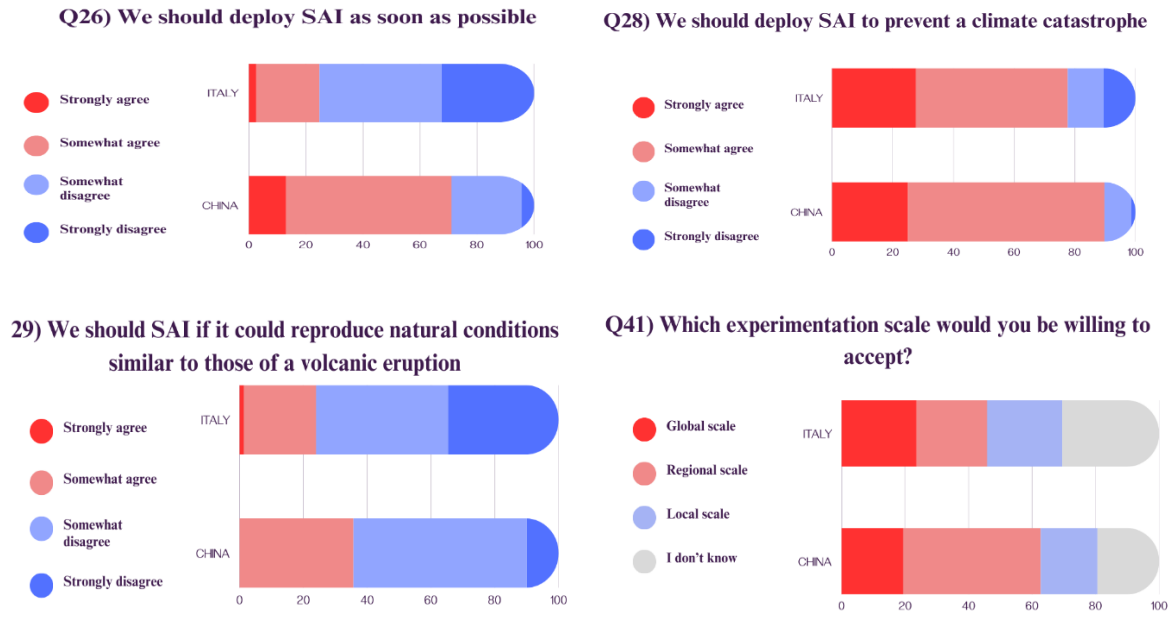


Table 2: Preliminary results

Survey results and discussion

Concerns over climate change

Respondents from both groups indicated fairly high confidence that anthropogenic-caused global warming was occurring. More than 90% of all students expressed the belief that global warming was happening (Q2), and a strong majority indicated that it was primarily caused by human activities (Q3). The degree of concern (Q4) over the impacts of global warming was also fairly high though it exhibited a stronger level among the Italian respondents (China: 60% 'somewhat worried'; Italy: 60% ‘very worried)

Similarly, the perceived level of individual adaptation necessary to cope with a changing climate (Q5) was higher among Italians, with 85% of respondents expressing the need to radically or partially change their habits and behaviors, whereas among the Chinese group less than 10% of respondents expressed the need to radically change their personal actions to help combat climate change.

Finally, both groups expressed that their country ought to exert some efforts to mitigate climate change even though such efforts might cause a varying degree of economic consequences (Q6). Italian respondents largely agreed that their government should exert a large effort even if it might yield considerable economic impacts (77%), whereas the attitudes of Chinese respondents were split between a modest effort with moderate impacts (49%) and a large effort with large economic consequences (36%).

Public awareness and attitudes towards SAI deployment

Currently, the Italian population does not exhibit widespread awareness of geoengineering (Q24) with more than 70% of respondents replying they had never heard of it or that knew only very little. Contrary to previous results (Sugiyama, 2020), the majority of Chinese respondents exhibited a similar degree of unawareness (63%). Overall, twenty-nine out of the 200 respondents reported difficulties in understanding the video (Q25).

Echoing past surveys and focus groups (Visscher et al., 2017; Sugiyama et al., 2020; Baum et al., 2024), my findings revealed a more positive attitude toward SAI implementation among Chinese students (Q26) with more than 70% of respondents agreeing that we should deploy SAI as soon as possible whereas Italian students exhibited much more caution regarding immediate deployment. However, both countries tended to favor retaining SAI as an option (Q27), expressing total or somewhat disagreement with excluding SAI completely.

I have already discussed the influence of discourse framing on respondents 'perception of SAI in the preliminary results, like the emergency (Q28) and the naturalness (Q29) framings. As for the link between SAI and abatement (Q30), a majority in both groups (China: 78%; Italy: 61%) would be willing to accept the use of SAI to allow industrialized countries more time to meet the decarbonization objectives. Finally, a strong majority of respondents (China: 89%; Italy: 72%) expressed the belief that SAI should be deployed to restore the harmony between humans and nature and not to control nature (D31).

Trust in institutions

Respondents were asked to express their degree of trust in the following institutions: government (Q12); environmental organizations (Q13); media (Q14); government-funded research on geoengineering (Q15); United Nations (Q16); European Union/ASEAN (Q17). The salient feature of this section is the seemingly shared attitudes in all respondents for all the institutions proposed, except for the government. Indeed, this was the sole question in which sentiments on trust between the two groups diverged. A minority of Italians expressed 'partial trust' in their government whereas most Chinese respondents displayed 'total trust.' Trust in institutions is an important proxy to determine people's affective feelings and cognitive evaluation of SAI that in turn might increase or lower support for field trials (Sugiyama et al., 2020). My findings tentatively revealed that a different attitude toward institutions might lead to support for different governance strategies (Table 3). Finally, a notable trait is the similar degree of trust expressed by respondents for all the other institutions (Q13-Q17). All students displayed a prevailing moderate level of trust for all the institutions proposed except for the media, which was mostly mistrusted, echoing previous results (Sugiyama et al., 2020).

Reluctant support of SAI outdoor research

The attitudes towards SAI field trials were split into different approaches (Q32). The propensity for plain support of outdoor research was low in both groups. Nearly half of the Chinese respondents (47%) exhibited a reluctant support for open-field experiments while nearly half of Italians (45%) were against SAI outdoor research, expressing support for lab research or opposing any kind of experimentation. The results reflected previous survey and workgroup findings that revealed stronger support for small-scale field testing among the population of the Global South (Visscher et al., 2017; Low et al., 2024, Baum et al., 2023; Baum et al., 2024). The results from Low et al. nuanced such preliminary insights showing that “global South focus groups exhibit greater hope but an arguably richer range of concerns for solar geoengineering" (: 11). They argued that researchers and policymakers should be cautious to interpret the positive attitude toward small-scale field tests as broad support for deployment.

Regarding the most appropriate level of regulation for SAI field trials (Q33), respondents were presented with six different options. The majority of both groups acquiesced that an international agreement would be the most appropriate policy instrument (China: 57%; Italy: 81%). However, a minority of Chinese students showed a proclivity for national regulation

(China: 17%; Italy: 2%). These data reflect previous surveys (Sugiyama et al., 2016, Baum et al., 2024) and workshop results (Low et al., 2024) that revealed that demands for an international framework are widespread among the public in the Global North and Global South. Low et al. argued that international cooperation to forestall any kind of geopolitical contestation is a key rationale for multilateral governance. However, the strongest support for national regulation among the Chinese might be derived from the higher trust in the government (Q12) and it might echo previous results by Baum et al. (2024) that suggested that in the Global South, "a more positive assessment of benefits and risks should thus be seen in tandem with a strong regime of national regulation and oversight – plus international collaboration" (: 889). Also consistent with previous findings is the low support for a moratorium (China: 0%; Italy: 8%).

Consensual demand for SAI research governance

Despite the different levels of support for SAI research and deployment, both groups agreed on the need for the governing principles of SAI research, epitomized by the Oxford and the Tollgate principles. When asked about the conditions for SAI field testing to take place, nearly all students from both groups either totally or somewhat agreed on the need for public engagement, transparency – even for negative results, and an inclusive approach to the moral permissibility of SAI. Notably, respondents were presented with a quote from American philosopher Dale Jamieson (Q35) that was extrapolated from the following passage: "No decision to go forward with geoengineering could be morally acceptable that did not in some way represent all of the people of the world. Even if people in poor countries would benefit from geoengineering it would still be wrong to change their climate without their consent" (Jamieson 1996, in Wong, 2013: 352). This statement makes sense from the Western liberal-democratic perspective because individuals have a right to be free and thus should be consulted about and given justifications for any decisions and actions that interfere with their ways of life (Wong, 2013). In contrast, the Confucian notion of personhood is relational, developmental, and virtue-based (Yu and Fan, 2007), which implies a different understanding of equality. Therefore, different people ought to be differentiated in their degree of virtuousness and capacity (Wong, 2013). Hence, in Confucian societies, the uneven distribution of power is a precondition for any form of decision-making. Accordingly, Wong suggested that "the Confucian view of the person does not vindicate the idea that each and every individual is to be viewed as equal […] instead, it takes virtuousness and capability as the criteria for being decision-makers" (: 359). Following Wong's elucidation, I was interested

in scrutinizing this gap that has been unaddressed in earlier surveys and exploring whether Jamieson's quote would have sparked different responses between the two groups. My findings, however, do not show any relevance that could uphold Wong's argument as both Chinese and Italian students largely agreed with Jamieson's assertion, echoing previous survey results (Sugiyama et al., 2016; 2020).

However, more ambivalent results revealed variations in attitudes across the two countries and might tentatively suggest support for Wong's theorization of the virtue-based approach to public engagement. When asked which countries should be included in the governance of small-scale outdoor research (Q37), both Italian and Chinese students expressed the belief that all the affected countries should participate in the governance (China: 92%; Italy: 99%). However, a majority in the Chinese group also exhibited support for governance mechanisms that involved only the more technically capable countries, without including all the affected stakeholders (Q38) whereas most Italian respondents disagreed with this non-inclusive form of governance. This finding aligns with Sugiyama et al. (2020). Moreover, as per which countries should take the initiative in the governance of SAI field trials, both students from China and Italy felt that more technically capable countries should lead SAI research (China:55%; Italy: 47%). Among Italian students, a minority (22%) expressed that high-emitters should take a lead role.

Finally, two statements (Q39, Q40) were aimed at gauging the perceived relevance of public engagement in science and early technology appraisal. Following the results of Low et al. (2024), participants' broad agreement for public involvement is often offset by strong skepticism over the value of public engagement – held likewise in groups across the Global North and South. The two opposing reasons for this skepticism are the strong trust in expertise in the government that renders public participation a futile exercise; and a deep sense of powerlessness and a lack of trust that the government would take public concerns into account. Low et al. reported that the first reason was particularly strong among the Chinese public whereas the second was more felt by countries in the Global North. Question Q39 followed the first rationale stating that public engagement was futile due to the irrelevance of public opinions in technoscience decision-making. This view implies a strong trust in authority that might be an expression of the Confucian's virtue-based ethics. In contrast, question Q40 followed the second reason, in which public participation was deemed irrelevant due to people's inability to influence political decisions. Most students disagreed with both statements, implying that public opinions are relevant both to the goals of scientific

research and to improve public policy. These results seem to support the three rationales for public participation succinctly summarized by Andy Stirling and adapted to the geoengineering debate by Frumhoof and Stephens (2017). Students' responses suggest that public participation in SAI research is the right thing to do, it provides better means to achieve the same results, and it leads to better outcomes.

Confucian ethics

Following the analysis of Wong (2015), Yu and Fan (2007), Cline (2014), and Kam Por Yu (2010), respondents were presented with questions about particular features of Confucian ethics that might present a different viewpoint on some specific arguments related to SAI research. These include: (1) the primacy of practice over theory; (2) the argument of 'playing God' and human hubris; (3) the notion of personhood; and (4) the ontological view of human-nature relation.

The epistemological attitudes of Chinese and Italian students displayed some divergence. Chinese respondents favored practical knowledge whereas the Italian group expressed disagreement with the primacy of practice over theory (Q23). It is noteworthy that the early Confucian epistemological perspective did not make a sharp distinction between theoretical knowledge and practical knowledge (Wong, 2012). Notably, the notion of *Dao* is a fundamental principle of Confucianism that organizes and governs the universe. This term has been used in several ways and an exhaustive account will not be provided here. I wish to briefly introduce the epistemological connotation of this principle that might allow for a broader discussion of the survey results. *Dao* represents an epistemological normative "insofar as it specifies the *good* and the *right* ways to do things" (Wong, 2012: 70). In Confucian thought, theoretical knowledge is often subordinated to the practical and pragmatic dimension of learning. This view has been supported also by a philosophical-linguistic perspective (Wong, 2012). Chinese Mandarin is not truth-apt but an action-guiding language and therefore it does not strive to the representation of Truth, but it aims primarily to seek a practical understanding of nature. *Dao* possesses also a metaphysical connotation as it is a manifestation of the spiritual dimension of Chinese thought, which is called Heaven. Ancient Chinese thinkers distinguished between Heavenly and Human Dao. The first might be understood as the Western concept of 'God,' whereas the second is an instantiation of the first in human society and politics and it refers to the "way human beings *should* live […] and the way the ruler *should* rule the people and society" (: 70). The epistemological prescriptions of

the Human Dao into the worldly affairs focuses on people's acquisition of virtues but does not provide universal norms and moral principles, because these are defined by the virtuous persons. The manifestation of *Dao* into human and social affairs marks the priority of the practice in Confucianism, "because Confucians believe that it is only pertinent to investigate the worldly affairs, i.e., the Human Dao, rather than unworldly, abstract *Dao* of Heaven" (: 71). In the survey, an analysis has been conducted to examine the effect of these factors on public acceptance of SAI field trials. Notably, the epistemological standpoint of respondents (Q23) has been compared with their attitudes toward SAI deployment (Q26) and research (Q32). Results from this analysis show a positive association between the perceived priority of practical knowledge over theoretical knowledge and the positive attitude towards SAI. This distinct cultural nuance, stemming from a different epistemological perspective, may play a significant role in fostering a higher acceptance of SAI deployment (Table 3). Similarly, respondents who prioritize practical knowledge seemed to exhibit a more open approach – though mostly reluctant – to the support of outdoor research. On the contrary, respondents who disagreed with the primacy of practice over theory displayed a more conservative approach.

	Q26: Agree	**Q26: Disagree**	**Total**
Q23: Totally Agree	China: 17 Italy: 0	China: 8 Italy: 0	China: 25 (36%) Italy: 0 (0%)
Q23: Somewhat Agree	China: 29 Italy: 8	China: 6 Italy: 17	China: 35 (51%) Italy: 25 (33%)
Q23: Somewhat Disagree	China: 3 Italy: 9	China: 5 Italy: 29	China: 8 (12%) Italy: 38 (51%)
Q23: Totally Disagree	China: 0 Italy: 2	China: 1 Italy: 10	China: 1 (1%) Italy: 12 (16%)
Total respondents	China: 49 Italy: 19	China: 20 Italy: 56	China: 69 Italy: 75

Table 3: Positive association between the preference for practical knowledge (Q23) and positive attitude towards SAI deployment (Q26). The value corresponds to the number of respondents.

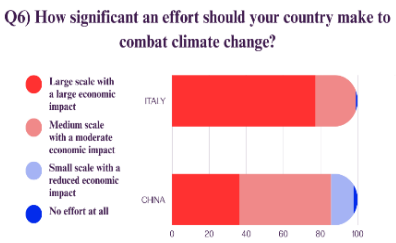
	Q32: Willingly or reluctantly accept	Q32: Accept lab research	Q32: Reject any research	Total
Q23: Totally Agree	China: 20 Italy: 0	China: 2 Italy: 0	China: 0 Italy: 0	China: 22 (37%) Italy: 0 (0%)
Q23: Somewhat Agree	China: 26 Italy: 14	China: 3 Italy: 7	China: 2 Italy: 8	China: 30 (51%) Italy: 23 (33%)
Q23: Somewhat Disagree	China: 4 Italy: 15	China: 3 Italy: 15	China: 5 Italy: 13	China: 7 (12%) Italy: 35 (50%)
Q23: Totally Disagree	China: 0 Italy: 7	China: 0 Italy: 4	China: 1 Italy: 8	China: 0 (0%) Italy: 12 (17%)
Total	China: 50 Italy: 36	China: 8 Italy: 26	China: 1 Italy: 8	China: 70 Italy: 75

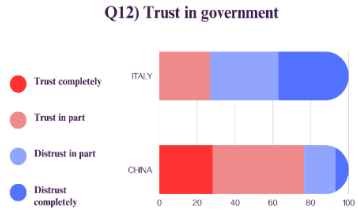
Table 4: Positive association between the preference for practical knowledge (Q23) and positive attitude towards SAI outdoor research (Q32). The "I don't know" replies were eliminated (China: 11 respondents; Italy: 5 respondents). The value corresponds to the number of respondents.

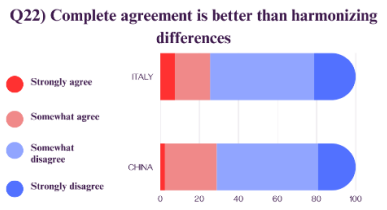
In addition, regarding the arguments of moral appropriateness (Q8) – also known as 'playing God' – and hubris (Q11), both groups agreed that deliberate climate modification is an act of human arrogance (China: 88%; Italy: 75%). Both arguments are a critique of the idea of geoengineering as it represents an aspiration to acquire certain qualities that humans cannot and should aspire to. Playing god signifies humanity's audacious overreach into realms of control. This act of defiance challenges fundamental boundaries and poses profound ethical dilemmas. Accordingly, humans should not overstep into the domain of nature and respect the limits of their ontological boundaries. As Wong argues, the human-nature relationship is at the heart of the argument from hubris or 'playing god'. Western perspective prescripts a radical separation between humans and nature - either ontologically, intellectually, or morally—arguing that the fusion of humans and nature is fundamentally and morally problematic. In contrast, the Confucian anthropocosmic worldview understands humans and nature as one entity connected by the principle of the *Dao*, as prescribed by the famous quote *tianrenheyi* 天人合一, *Heaven and humans are one*. Therefore, the two arguments might not be shared by the Confucian perspective. As Wong (2015) cautiously explained, to consent to human intervention in nature – even large-scale – is "not to assert that every person should

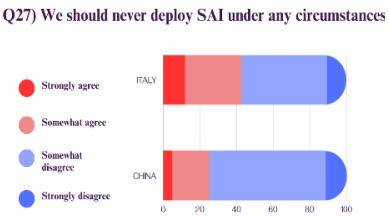
aspire to god-like qualities—and, in this case, the capability to engineer the climate—but only to assert that an aspiration to those qualities need not to be fundamentally wrong in the moral sense" (: 36). My results, however, do not seem to reflect this ontological nuance. Surprisingly, most of the Italian (61%) students rejected the idea that emulating nature through technology is morally wrong whereas more than half of Chinese respondents agreed (59%).

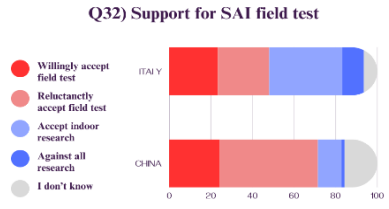
Regarding the belief in the notion of personhood, both groups exhibited an attitude closer to the liberal-democratic perspective. Most students believed that a person is independent (Q19), rational, and self-determining (Q20). Finally, the majority in both groups abided by the Confucian tenets of *tianrenheyi*, which marks the unity between humans and nature (Q21). The results among the Italian students, however, might be biased by their university major in environmental science and humanities (China: 72%; Italy: 96%). Similarly, most students concurred that harmonizing differences is better than total agreement (Q22) (China: 71%; Italy: 74%).

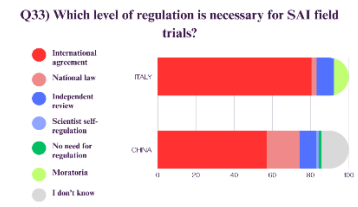


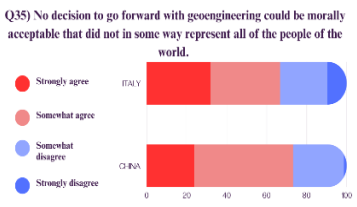












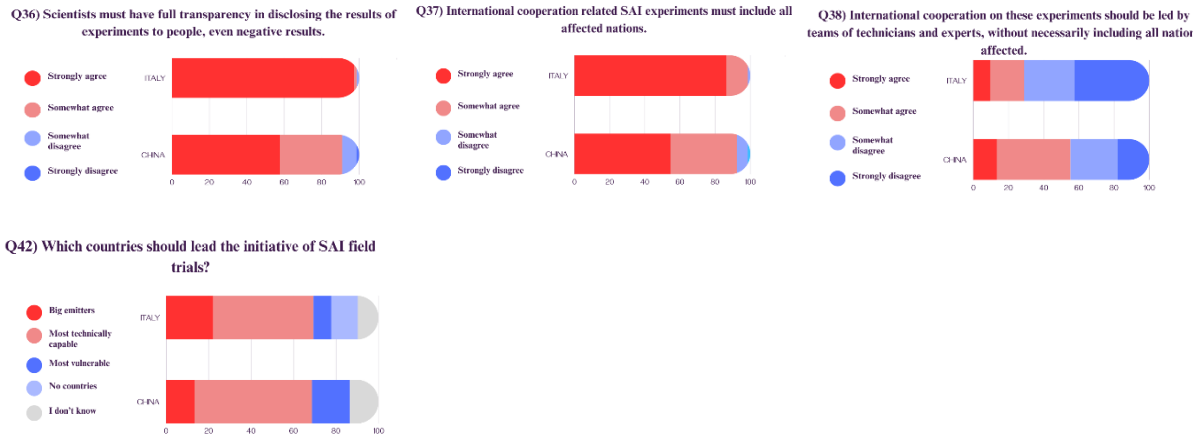


Table 5: Survey results.

Survey limitations

Five notable limitations of the present study warrant attention:

1. Surveys are a form of opinion polls that often fail to capture the complexity of participants' views (Sugiyama et al., 2016) and can produce skewed results due to framing effects (Visschers et al., 2017). Terms like ‘emergency’ or ‘naturalness’ can unduly influence respondents' perceptions (Corner, 2011). Consequently, my findings may only offer a glimpse into the intricate nature of people's perceptions of SAI.

2. The visual material provided to respondents offered only limited insights into the time scale of climate change and the potential side effects of stratospheric aerosol injection. It is crucial to recognize that participants may not have had a comprehensive understanding necessary to accurately assess the climatic risks and ethical implications of solar radiation management.

3. Given the current low level of awareness of SAI, the survey results may reflect only superficial opinions or constructed preferences. These opinions are particularly vulnerable to change as new information emerges or social contexts evolve (Sugiyama et al., 2016).

4. The comparison between Italy and China enriches our understanding of how cultural perspectives can influence public perception of novel technologies. However, the survey quantitative analysis primarily compared the responses of Chinese and Italian participants, highlighting a divide between the Rest and the West, which may inadvertently position the Western perspective as the normative standard. In other words, my thesis failed to provincialize the West in the way Japanese researchers did

in a comprehensive analysis of public perception of SAI among six Asia-Pacific countries (Sugiyama et al., 2020). This research breaks the dichotomy between the West and the Rest by referencing different Asian perspectives and values. It found a rich diversity of opinions within the Asia-Pacific region that most of the dominant literature homogenizes in the dualistic interpretation with the West.

5. The different educational backgrounds among participants might have restricted a sensible cross-country comparison in my survey sample. The higher awareness of climate change among students of environmental science has been indicated as a potential bias for surveys on geoengineering (Sugiyama et al., 2020). The strong ecological mindset among students in environmental science and environmental humanities likely played a crucial role in their increased rejection of deliberate climate modification. Furthermore, a key limitation of the survey is its small respondent pool, which lacks national representation and may not accurately reflect broader public opinions.

Conclusions

Due to the planetary scale of solar radiation management techniques, an inclusive and global conversation is deemed essential for effective governance. Geoengineering entails potential unintended global environmental consequences, ethical sensitivities, and complex trans-boundary governance issues (Corner et al., 2011). The Royal Society (2009) called for the first activities of public engagement to understand public responses to these concerns. Since then, a growing body of scholarly journals has engaged in research on public perceptions of SRM and other geoengineering proposals. However, this research has been mostly limited to the Global North and predominantly assumed the Western liberal-democratic view as a benchmark. This thesis has offered a critical review of the literature on public engagement with SRM based on the post-colonial studies on geoengineering. Notably, the Confucian ethical framework has been adopted to nuance the results of past research that too often neglect alternative ontologies and worldviews. Following the knowledge gaps of the dominant research on public engagement with science, I crafted a comprehensive survey aiming to investigate the different perspectives between Western and Confucian views on the SRM proposal known as stratospheric aerosol injection (SAI).

My findings identified a more positive attitude toward SAI implementation among Chinese students whereas Italian students exhibited much more caution regarding immediate deployment. Responses revealed that both groups support SAI deployment under the emergency framing, but Italian respondents exhibited a higher internal conflict derived from the influence of such framing. Results revealed a different degree of trust in government that might lead to support for different governance strategies. Despite the different levels of support, both groups agreed on the need for the governing principles of SAI research, including public engagement, transparency – even for negative results, and an inclusive approach to the moral permissibility of SAI. However, a majority of Chinese respondents exhibited support for governance mechanisms that involved only the more technically capable countries, without including all the affected stakeholders whereas most Italian respondents disagreed. Furthermore, the epistemological attitudes of Chinese and Italian students displayed some divergence. Chinese respondents favoured practical knowledge whereas the Italian group expressed disagreement with the primacy of practice over theory. The epistemological standpoint of respondents has been compared with their attitudes toward SAI deployment and research. Results from this analysis show a positive association between the perceived priority of practical knowledge over theoretical ones and the positive attitude towards SAI. This distinct cultural nuance, stemming from a different epistemological perspective, may play a significant role in fostering a higher acceptance of SAI deployment. Similarly, respondents who prioritize practical knowledge seemed to exhibit a more open approach – though mostly reluctant – to the support of outdoor research.

Finally, we can draw five lessons for the future governance of SAI based on the world's responses to COVID-19. Although the pandemic and climate change operate on different timescales, responses to both crises must navigate the same "science-media-policy environment" (Buck et al., 2020):

1. *Narrow metrics*: during the COVID-19 pandemic state policy narrowly focused on single measurable parameters – case count, the reproduction number (R0) - with the result that this narrow metrics became the target policy and started to define the solution. Similarly, climate policy focuses on the single metric of global average temperature, therefore a solution like stratospheric aerosol injection might be attractive. However, average temperature is a proxy of several multi-scale socio-ecological impacts, and therefore a governance framework is needed to take into

account the broader range of goals and ancillary effects of climate modification measures.

2. *Missing global governance*: the COVID-19 pandemic highlighted the fragmentation of international politics where each country pursued different priorities. The competition for vaccines, medicines, and equipment revealed the absence of a global governance structure or even an algorithm. Indeed, the governance modeling of SAI relies on the assumption of a comprehensive global governance to reach a global aim when in fact this regulator does not exist.
3. *Media technologies*: during the pandemic, media platforms had a strong influence on societal debates about science, creating both cohesion and divergence. Notably, media outlets and public views became polarized on a single narrative of the scientific facts and such a dynamic is particularly worrisome for the future public appraisal of SAI. Besides scientific findings that influence media publications, the opposite dynamic is least understood. For SAI, scientists could be encouraged to produce knowledge on questions with a strong narrative appeal to the detriment of the pursuit of equitable science.
4. *Policy visibility*: the mask mandate was arguably a highly visible and low-cost preventive measure that led to extensive debates that might have drawn attention away from more complex policy challenges, such as the protection of the elders and the most vulnerable in care homes. Likewise, SAI may become a similar performative measure used to mask[26] the political failure of climate adaptation or mitigation and draw focus away from other climate goals.
5. *Stopgap measures*: during COVID-19, lockdowns had the strategic goal to buy time for longer-term action. Yet, this strategy entails the risk that the initial objective is forgotten, and eventually maintaining the stopgap becomes the goal, or that the time that is bought is not used efficiently. SAI is a notable stopgap measure that can buy time for abatement efforts to increase. As COVID-19 illustrated, to prevent SAI from becoming an interminable stopgap, the public must be well-informed about the goal, duration, and nature of the stopgap measure and politician must be held accountable for their failure to efficiently use the time bought.

[26] *Pun*!

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