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Ambivalent climate of opinions: Tensions and dilemmas in understanding geoengineering experimentation

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ABSTRACT

Due to the fear of the consequences of climate change, many scientists today advocate the research into—but not deployment of—geoengineering, large-scale technological control of the global climate, to reduce the uncertainty around its efficacy and harms. Scientists propose in particular initiating field trials of stratospheric aerosol injection (SAI). This paper examines how the meanings of geoengineering experimentation, specifically SAI field trials, are reconfigured in the deliberation of the lay public. To this end, we conducted focus groups with Japanese citizens in June 2015 on the geoengineering concept and SAI field trials. Our main findings are as follows: the 'climate emergency' framing compelled the lay public to accept, either willingly or reluctantly, the need for 'geoengineering research'; however, public discourse on SAI field trials was *ambiguous* and *ambivalent*, involving both tensions and dilemmas in understanding what the SAI field trial is for and about. Our results exhibit how the lay public wrestles with understanding the social, political, and ethical implications of SAI field trials in multiple dimensions, namely, *accountability*, *controllability*, *predictability*, and *desirability*. The paper argues that more clarity in the term 'geoengineering research' is needed to facilitate inclusive and pluralistic debates on geoengineering experimentation and not to preemptively arrive at a consensus that 'we need more research.' We conclude that ambivalence about both the pros and cons of geoengineering experimentation seems to be enduring; thus, instead of ignoring or repressing it, embracing ambivalence is required to keep the geoengineering debate democratic and inclusive.

1. Introduction

In the last decade, the idea of deliberate manipulation of the earth's climate to counteract anthropogenic climate change, known as geoengineering or climate engineering, has been increasingly incorporated into the mainstream climate debate as a potential response option (IPCC, 2012, 2014). However, the prospect of geoengineering frightens people because such manipulation of the nature generates deep uncertainty over the climate system, and therefore might result in unintended, unpredictable, and uncontrollable negative—potentially catastrophic—consequences (e.g. Robock, 2008). Geoengineering may fundamentally alter the relationship between human and nature or significantly undermine political efforts toward mitigating climate change, which has induced strong ethical condemnation (e.g., Hamilton, 2013; Gardiner, 2010). Despite these downsides, geoengineering creates an "atmosphere of hope" (Flannery, 2015), a feeling that it is the only option that may ward off dangerous climate change. The vision of geoengineering is emotionally anchored between hopes and fears, and is imbued with ambivalence about the choice of futures (Asayama, 2015).

The term 'geoengineering' is used to cover a diverse and heterogeneous group of putative technologies, commonly divided into two distinctive categories: solar radiation management (SRM) and carbon dioxide removal (CDR) (Royal Society, 2009). While SRM is to reduce incoming sunlight and reflect it back to space, CDR is to remove carbon dioxide (CO_2) from the atmosphere. Most geoengineering technologies are still hypothetical, existing so far only as computational imaginaries represented in climate models (Kravitz et al., 2013a,b), or as discursive realities in policy reports (Huttunen et al., 2015) and news media coverage (Nerlich and Jaspal, 2012; Anshelm and Hansson, 2014a,b; Luokkanen et al., 2014). Geoengineering is not (yet) a physically-tangible technological object, so what constitutes geoengineering? It is the very idea that humans attempt to technologically control the global climate,

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i.e., the provision of setting a global thermostat for the planet (Hulme, 2014). Because it essentially places the earth itself on an experimental stage, geoengineering can be seen as a discourse of *experimentation*.

The case of the SPICE (Stratospheric Particle Injection for Climate Engineering) project in the UK illustrates the experimentality of geoengineering. The SPICE project attempted to conduct a field experiment of geoengineering, though it was eventually canceled due to a conflict of interest related to a patent application. The SPICE trial was experimental in many senses, not only because it was the UK's first field test of geoengineering technology but also, and more importantly, because it was a social experiment that involved extra-scientific scrutiny, such as public engagement exercises with lay citizens (Pidgeon et al., 2013; Stilgoe et al., 2013a; Stilgoe, 2015). The SPICE case indicates that engaging the public in geoengineering is part of "an experimental system [of geoengineering] in which knowns and unknowns are negotiated, in public discourse and in research projects" (Stilgoe, 2016, p. 853; see also Bellamy and Lezaun, 2015).

There is now a chorus of scientists calling for 'more research' on geoengineering. Scientists are especially proposing to start field trials of stratospheric aerosol injection (SAI), a technology that involves spraying reflective particles into the stratosphere to reduce solar radiation, and which is considered one of the most emblematic geoengineering technologies (Hulme, 2012). However, field experiments of SAI are subject to controversial debates, can be seen as an archetype of "post-normal science" (Funtowicz and Ravetz, 1993) that requires wider public consultation with various stakeholders and lay citizens (Carr et al., 2013; Sugiyama et al., 2017).

This study examines how the meanings of geoengineering exp erimentation—specifically, SAI field trials—are rearticulated and reimagined as public discourses in the lay public's deliberation. We conducted focus groups with Japanese citizens on the very idea of geoengineering and on the proposal of SAI field trials. Our results show how the lay public wrestled to understand the experimentality of SAI field trials in multiple ways, and faced a dilemma between hopes and fears for technological experiment of our climate and society.

As we will discuss later, lay public discourse on geoengineering experimentation abounded in *ambiguity* and *ambivalence*. Although both ambiguity and ambivalence have something to do with uncertainty and unclearness, ambiguity is rather about incomplete knowledge or *epistemic* pluralities (e.g. framings, perspectives, assumptions) (Stirling, 2007), while on the other hand, ambivalence is more related to conflicts of values, worldviews or *normative* judgments. In this paper, we refer to 'ambiguity' as that deals with vagueness or indeterminacy resulted from plural and contended meanings, and to 'ambivalence' as that indicates attitudinal inconsistency in which people are "actively struggling to formulate opinions incorporating contradictory normative positions" (Cairns and Stirling, 2014, p. 31).

2. Background

2.1. Call for 'more research' on geoengineering

The debate on geoengineering is surrounded by controversy. This controversy concerns not only the risks and benefits brought into by geoengineering but also people's worldviews, i.e., "the kinds of world [geoengineering] deployment would bring into being" (Macnaghten and Szerszynski, 2013). There is a fundamental disagreement in "epistemic cultures" (Rayner, 2015), related to whether we should deliberately intervene in the climate. Despite this irreconcilable clash of values, the geoengineering debate by and large has converged into a call for 'more research' on geoengineering (Anshelm and Hansson, 2014b; Huttunen et al., 2015). Reports from both the UK Royal Society and the US National Research Council highlighted that geoengineering is no substitute for mitigation and adaptation; at the same time, both reports acknowledged the potential usefulness of geoengineering and hence recommended 'more research' to figure out whether geoengineering can be a viable option in the future (Royal Society, 2009; NRC, 2015).

Importantly, this advocacy of geoengineering is not for deployment but for *research* (Linnér and Wibeck, 2015). Given the significant potential risks pertaining to geoengineering, scientists usually consider it as a non-ideal or undesirable option (Robock, 2008). However, they do not rule out the possibility of geoengineering because of their anxiety about catastrophic climate change. Thus, scientists often take an ambiguous *and* ambivalent attitude toward geoengineering, citing both its benefits and its risks and remaining undetermined with regard to its deployment (Scholte et al., 2013; Huttunen et al., 2015; Hansson, 2014; Linnér and Wibeck, 2015). This ambivalence can easily turn into the well-worn scientist cliché that 'we need more research' because there is huge uncertainty over geoengineering.

The discourse of 'more research' is underpinned by our ignorance (Rayner, 2015). Whether supporting or opposing further research into geoengineering, we can all agree that our knowledge of how geoengineering technologies would work is inadequate. A lack of knowledge doesn't immediately justify the research into geoengineering; we still can choose not to research it (Hulme, 2014). However, under the circumstance with profound uncertainty, the call for 'more research' sounds straightforward and discreet, at least for scientists, because 'more research' could also lead to our abandoning geoengineering options if it became clear that the risks of geoengineering far outweighed its benefits. This perspective presupposes that research and deployment of geoengineering are separable, and therefore should be separated (e.g., Cicerone, 2006). Because of our ignorance, scientists usually consider that 'more research'—but not deployment—can be justifiable for advancing our understanding of geoengineering. In short, it is argued that "ignorance is not an option" (McNutt, 2015).

As such, the call for 'more research' is built on a widespread assumption (or faith) among scientists that 'more research' can reduce uncertainty (or produce 'more knowledge'), so that we can make better decisions in the future (e.g., Keith, 2013; Robock, 2012). This assumption is problematic because it would reproduce a linear model of the science–policy interface (e.g., Pielke, 2007; Beck, 2010) and reinforce the scientism that supposes 'more knowledge' can provide a decisive answer to social problems, thus defusing political controversy and public opposition by leaving normative questions untouched (e.g., Wynne, 2001). Nonetheless, the rhetoric of 'more research' is so powerful and thereby repeatedly used when scientists are tempted to convince policymakers and other stakeholders and to gain wider public support. The question is then often framed in terms of *how* we should do research but not *whether* we should do research. Scientists have taken the necessity of geoengineering research for granted by imagining the speculative future of catastrophic climate change, and also by rhetorically distinguishing research from deployment. So, the pressing issue lying on scientist's minds is how we can responsibly govern geoengineering research (cf. Dilling and Hauser, 2013).

Altogether, from the scientist's point of view, the need for 'more research' on geoengineering seems indisputable. Lay citizens may find it irrefutable, or at least hard to argue against scientists calling for 'more research,' especially when the argument is framed in the context of 'climate emergency' (Corner et al., 2011), because it is a normative call for taking action against climate change and does not propose immediate deployment (cf. Gardiner, 2010). But, of course, this doesn't mean that citizens should give a carte blanche to scientists whatsoever geoengineering research may be. In fact, what does 'geoengineering research' really mean when scientists say 'more research is needed'? What kinds of research do they want to do? What technology proposals fall into the geoengineering category? As a matter of fact, what a growing number of scientists are advocating is the field trial of SAI.

2.2. Field trial of stratospheric aerosol injection (SAI)

SAI is based on the idea of mimicking the cooling effects of large volcanic eruptions by spraying small reflective particles (e.g., sulfates) into the lower stratosphere (Royal Society, 2009; NRC, 2015). The eruption of Mount Pinatubo in the Philippines in 1991 released 20 megatons of sulfur dioxide gas into the stratosphere, producing a sulfate aerosol cloud that blocked incoming sunlight, cooling the planet for a couple of years by roughly 0.5 °C (Robock et al., 2013). SAI has received most attention from scientists because of its rapid cooling effect and its affordability compared to the cost of substantial climate mitigation[1] (e.g., Barrett, 2008). When scientists talk about geoengineering, they are most often referring to SAI (cf. Linnér and Wibeck, 2015).

From computer modeling research, SAI is known to produce both benefits and risks (Irvine et al., 2016). While it can quickly reduce global mean temperature, SAI—like other SRM techniques—has nothing to do with reducing CO_2 concentration in the atmosphere and hence cannot stop ocean acidification. SAI may potentially cause, depending on the scale of deployment, adverse impacts on the environment, such as ozone layer destruction and regional precipitation changes. Yet, there remains deep uncertainty about the feasibility of SAI including the effects on local climates (e.g. Hulme, 2014). Furthermore, an uneven distribution of benefits and harms raises ethical and moral concerns about SAI (Svoboda, 2016). SAI may also pose political challenges to contemporary liberal democratic systems, as it could be an autocratic or totalitarian tool of so-called 'techno-fix' (Szerszynski et al., 2013; Hulme, 2014).

While the cooling effects of SAI have been widely recognized among scientists, its efficacy and harms have been demonstrated so far only in simulations (in silico experiments) on climate models but never tested in the natural environment—apart from one study conducted in Russia (Izrael et al., 2009). For this reason, some scientists—most notably David Keith (2013)—are proposing to conduct field trials (in situ experiments) of SAI in order to increase the knowledge about its feasibility (Caldeira and Keith, 2010; Keith et al., 2010; Parson and Keith, 2013; Morgan et al., 2013; Victor et al., 2013; Long et al., 2015). However, this advocacy for SAI field trials has not received unanimous support, and instead has become a subject of controversy among scientists.

Proponents of SAI field trials suggest starting from small-scale experiments that would carry little or no direct physical risk, and gradually expanding to larger-scale ones that may pose measurable local or global risks of which the magnitude depends on the size of the experiment[2] (Blackstock et al., 2009; Dykema et al., 2014; Keith et al., 2014). Parson and Keith (2013) proposed setting two separate 'experimental thresholds': above an upper level, experiments should be a subject of temporal moratorium, whilst below a lower level, experiments can proceed as ordinary scientific research. Most proponents acknowledge that SAI field trials entail a number of social and political challenges, and that governance—either voluntary or mandatory—is necessary (Blackstock and Long, 2010; Parson and Keith, 2013; Parker, 2014; Long et al., 2015), but they basically think "the risks of not doing research outweigh the risks of doing it" (Keith et al., 2010, p. 426). Importantly, they presume that the boundary between small and large or experimental thresholds can be *technically* defined—i.e., whether experiments involve *physical* risks—and hence consider that 'small-scale, low-risk' field trials should be allowed to start now.

However, there is much opposition to starting SAI field trials. Fadeel et al. (2013) claimed that even small-scale trials would impose serious physical risks if hazardous particles were used. Robock et al. (2010) argued against outdoor experiments, saying that the effects of SAI cannot be tested in small-scale trials due to the noise of climate variation, and such effects are testable only in full-scale deployment. Although the purpose of small-scale trials is not to examine the climatic effects of SAI but to understand the processes of atmospheric chemistry (Keith et al., 2014), this unease about SAI field trials touches upon the difficulty of defining the boundaries or thresholds once experiments would go outside a laboratory. Robock (2012), on the other hand, drew a clear line between indoor and outdoor research, arguing for indoor research (e.g., computer modeling, laboratory experiments, etc.) but against outdoor research (i.e., field trials) until adequate regulatory governance is in place. Likewise, Schäfer et al. (2013) called for a moratorium on field trials until international cooperation is established.

Interestingly, these critics do not oppose SAI research in general but the SAI *field trial* in particular. In fact, Alan Robock (2012), who argues that "[t]he benefits of knowledge outweigh the risk of not knowing" (ibid., p. 228), embraces—just as David Keith (2013) does—the assumption that 'more research' will lead to 'more knowledge' and 'wiser decisions.'[3] Keith and Robock share ambivalence toward SAI too, seeing it as unwanted but maybe necessary in the future—Keith is, however, more optimistic about SAI than Robock. What sets them apart are their views on what kind of science the *small-scale* SAI field trial is. Keith considers it to be an extension of 'normal science' that requires strong transparency but no need for strict regulation, because it would not involve significant physical risks, whereas Robock considers that it goes beyond 'normal science' and thus should be prohibited in the absence of strict regulation, because it can potentially be dangerous. As Stilgoe et al. (2013b) described, Keith and Robock are different about *where* the experimental thresholds—either particular levels of radiative forcing or the doors of a laboratory—should lie, but both are same about their attempts to cordon off the 'safe zone' of SAI research that can be detached from politics.

The very fact of disagreement between Keith and Robock suggests that the SAI field trial is "post-normal science" surrounded by deep uncertainty and high societal stakes (Funtowicz and Ravetz, 1993), regardless of its scale. For example, although the SPICE field trial was intended to spray only a small amount of water to test the delivery system of SAI, it attracted fierce public criticism and "became an in foro public experiment even in absence of an actual in situ trial taking place" (Stilgoe, 2016, p. 863). Conducting SAI field trials means a symbolic move from the conventional and uncontroversial territory of experiments inside laboratory into the likely contentious and controversial realm of outdoor 'real-world' experiments—the experiments taking place in and with society (Gross, 2016), in which the boundary

[1] The latest review on the cost assessment of SAI revealed that previous studies underestimated the direct cost (not including the cost of negative side effects) of SAI deployment, which may not be as cheap as it has been commonly claimed like "a few billion dollars" (Moriyama et al., 2016).

[2] Keith et al. (2014) classified field experiments by purpose and physical scale into four categories: 'technology development,' 'process studies,' 'scaling tests,' and 'climate response testing.' In this typology, 'process studies' are seen as small-scale trials with little or no risk; 'climate response testing' is a large-scale trial indistinguishable from deployment; and 'scaling tests' are in between.

[3] In stark contrast to Keith and Robock, Mike Hulme (2014) has a radically different position, considering that 'more research' does not necessarily reduce uncertainty, instead there always remains irreducible ignorance (for details, see Rayner, 2015).

between research and deployment would be more blurred and unclear.[4] Any outdoor experiments of SAI, despite their scales, would involve some aspect of deployment while on the other hand, deployment would be itself experimental because of huge uncertainty involved (Stilgoe et al., 2013b). Therefore, the debate over SAI field trials cannot be confined only to the technical issues of efficacy or safety, nor can it be confined only to scientists and experts. The adequacy and validity of SAI field trials must be addressed from the standpoint of wider societal concerns (e.g., the concern that SAI field trials might be a step onto a 'slippery slope' toward deployment), and should be undertaken in upstream consultation with wider public audiences (Corner et al., 2012; Carr et al., 2013; Sugiyama et al., 2017).

The SAI field trial is to date still a proposal, only contemplated by some scientists, but there is a real possibility that this experiment will take place soon (cf. Cho, 2016). Thus, there is an urgent need to uncover broader public concerns over the SAI field trial *before* it starts.

3. Methods

The aim of this paper is to examine the public discourse on geoengineering experimentation, specifically SAI field trials. Unlike previous studies gauging the public acceptance of SAI research/experiment (Mercer et al., 2011; Merk et al., 2015; Sütterlin and Siegrist, 2016), our analytical focus is on digging deeply into how people understand in multiple ways—and reconstruct in their own terms—the meanings of SAI field trials, and thereby to deconstruct or "unframe" expert discourses (Bellamy and Lezaun, 2015).

To explore the way the lay public understands the idea of geoengineering and the proposal of SAI field trials, we employed the focus group method in a similar way with Macnaghten and Szerszynski (2013) and Wibeck et al. (2015). The focus group is a useful method to analyze how people generate their own opinions, questions, and frames about a particular topic in their own words (Barbour and Kitzinger, 1999). It can allow for people to elicit their own understanding through group interaction, even without prior knowledge of the issue discussed (Wibeck et al., 2015; Malone et al., 2010). The focus group is also suitable for exploring ambiguity and ambivalence in people's interpretations, particularly for unfamiliar, controversial, or complex issues for which people often express their own views in a more nuanced way rather than with a simple yes or no (Bloor et al., 2001).

Six focus groups were carried out in Tokyo, Japan in June 2015, each with six participants and lasting roughly two hours. Thirty-six participants living in the Greater Tokyo area were recruited by a professional consulting firm. The participants were recruited to take part in a discussion on 'everyday life issues,' in order to make the recruitment topic-blind: the terms 'geoengineering' and 'climate change' were not mentioned in the recruitment process. Participants were given a monetary honorarium for their participation. 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. Taking a similar approach with Wibeck et al. (2015), participants were divided into six groups by three demographic criteria: age, gender, and education (see Table 1).

The focus group discussions were moderated by an experienced focus group practitioner of the professional consulting firm. The authors observed each entire group discussions from a hidden monitoring room. The topic guide of focus groups was semi-structured, with open-ended questions (cf. Wibeck et al., 2015), broadly consisting of two separate parts: (1) exploring people's reactions to the idea of geoengineering (defined as 'artificial manipulation of the climate by large-scale technology'); and (2) exploring people's reactions to the proposal of SAI field trials. The first part of focus groups was based on Wibeck et al. (2015), with minor modifications. The moderator's involvement in the group discussions was limited in the first part so as to allow participants to speak spontaneously about their sentiments on geoengineering, and information about geoengineering was given verbally, aided by a few written texts but no visual images. In the second part, the moderator was more actively involved in the participants' discussions of SAI field trials; both visual images and written texts were used to help the participants understand the topic. The discussions were audio-recorded and transcribed verbatim; all names in the transcripts were anonymized by replacing the original names with pseudonyms. The focus groups were conducted in Japanese; all quotations in the paper have been translated by the authors into English and adapted to the conventions of written language.

Table 1
Focus group composition.

Group no.	Group characteristics		
	Age	Gender	Education
1	Young adults	Mixed gender	High school degree
2	(aged 25–35)	(3 men, 3 women)	College degree
3	Middle ages	Female	Mixed degree
4	(aged 36–50)	Male	(3 with high school, 3 with college)
5	Senior adults	Female	Mixed degree
6	(aged 51–65)	Male	(3 with high school, 3 with college)

The focus group discussions began with general questions about global environmental issues and climate change, and then moved to a discussion of policy responses to climate change, after a brief explanation of mitigation and adaptation. This was followed by a broad discussion on geoengineering. The concept of geoengineering was generally introduced, with strong emphasis on two characteristics: as a 'large-scale technology with global effects,' and as an 'artificial manipulation of the earth's climate.' In this phase, we tried to avoid imposing pre-existing framings (e.g., 'climate emergency') on participants, and the discussions focused on the very idea of geoengineering and its social, political, and ethical implications. Some examples of geoengineering technologies were mentioned—but very briefly and only verbally—for both SRM (space mirror, SAI, desert reflective sheeting, crop brightening) and CDR (direct air capture, ocean iron fertilization).

Subsequently, at the end of the first part, the 'climate emergency' argument was introduced. We were aware that the emergency framing is problematic, creating a biased condition that may force people to accept the argument for 'more research' (Corner et al., 2011). Nonetheless, this framing is still a dominant way of communicating about geoengineering (Nerlich and Jaspal, 2012; Bellamy et al., 2012) and constitutes a strong rationale for advocating SAI field trials (e.g., Caldeira and Keith, 2010). Thus, we *experimentally* employed the emergency framing to explore if it may or may not change the participants' views on geoengineering. We then ended the first part by asking for the participants' evaluation of geoengineering in comparison with mitigation and adaptation. Importantly, it should be borne in mind that subsequent discussions in the second part were also framed in terms of 'climate emergency.'

After a short break, we started the second part of focus groups with a somewhat more detailed explanation of SAI, including both

[4] As experiments inside laboratory (e.g. computer simulations) also, in a way, take place in the real world, such experiments are by no means immune to public scrutiny (Stilgoe et al., 2013b; Stilgoe, 2015). However, in our views, SAI field trials are by definition social experiments, thus ought to be differentiated somehow from indoor experiments.

its benefits (e.g., quick effect, low cost) and risks (e.g., declining crop production through precipitation changes, unpredictable negative side effects). In this explanation, the 1991 eruption of Mount Pinatubo was mentioned as an analog of SAI. This analogy may bias participants toward favoring SAI by giving them the impression that SAI is a 'natural' process (Corner et al., 2013; Corner and Pidgeon, 2015). However, we deliberately avoided the use of the idiom of naturalness (e.g., mimicking nature), and instead repeatedly emphasized that SAI is an *artificial* modification of nature.

We then moved to a discussion of SAI field trials by introducing three types of SAI research: (1) indoor research (e.g., computer modeling, laboratory experiment); (2) small-scale field trials (i.e., experiments involving little or no environmental impact); and (3) large-scale outdoor experiments (i.e., experiments involving actual environmental impacts, akin to deployment). It was explained that small-scale field trials have been a subject of controversy among scientists. The moderator stimulated participants to probe into the social, political, and ethical implications of conducting SAI field trials. Finally, the discussions were closed by asking the participants about their expectations of the scientists who propose SAI field trials, and of scientists in general.

The transcript data was analyzed interpretatively to identify key themes, framings, and discourses in focus group discussions. We divided all the transcript data into different segments and analyzed them separately. First, the data was divided into the first and second parts of the discussions, because different subjects were central to the group discussions. The first part was then divided into before and after the introduction of emergency framing. Thus, the data consisted of three segments with different main subjects: (1) initial reactions to the geoengineering concept (Section 4.1.1); (2) evaluations of geoengineering as climate change response (Section 4.1.2); and (3) social meanings of SAI field trials (Section 4.2). Through an iterative process of close reading and thematic coding, a wide range of core themes was identified. Thematic coding was done as follows: (1) categorizing and labeling the participants' utterances as sub-themes according to what these utterances signify; (2) assembling sub-themes that recurred throughout the focus groups; and (3) identifying core themes consisting of several sub-themes that capture abstract meanings relevant to the main subjects in each segment.

4. Results: Public discourse on geoengineering experimentation

4.1. Understanding the idea of geoengineering the climate

The participants had no prior knowledge of geoengineering before the focus groups. Almost all the participants answered that they had never heard of it before. Their first encounter with the idea of geoengineering evoked profound affective reactions, both positive and negative. People showed sharply contrasting views on geoengineering: some almost categorically rejected the idea of human manipulation of nature while others expressed enthusiasm for a grand-scale technological experiment. After the introduction of the emergency framing, however, their divergent stances swiftly changed to more ambivalent attitudes about the role geoengineering can play in responding to climate change. To put it shortly, people's opinions were at first divergent and contentious over the idea of geoengineering, and then, as a reaction to the emergency framing, became rather convergent but still ambivalent to geoengineering research.

4.1.1. Emotive anchoring of geoengineering concept

The very idea of geoengineering ('artificial manipulation of the climate by large-scale technology') evoked hopes and fears, optimism and pessimism, enthusiasm and skepticism. Our analysis revealed four emotively anchored framings that were affectively associated with geoengineering among participants: (1) 'frightening idea,' (2) 'ingenious attempt,' (3) 'implausible plan,' and (4) 'unnecessary solution.' The first three framings were prevalent in all groups but the fourth one was found in only half the groups.

First, 'frightening idea' is associated with feelings of fear, anxiety, and unrest. The words "scary," "terrifying," and "anxious" were frequently used when referring to unpredictable side effects and the idea of artificial manipulation. The *unimaginability* of unknown consequences was a common underlying theme. Some participants (G1, 2, 4, 5), however, could surmise the kinds of negative consequences that might be brought about by geoengineering (e.g., its impact on agriculture, the ecosystem, local weather, etc.) and were uneasy with them. One elderly male (G6) even worried about the risk of weaponization (cf. Robock, 2008), imagining a scenario in which this technology might be used by superpowers to threaten other nations. The fear of geoengineering was also related to concern over technical *irreversibility*; some proposals (e.g., space mirror, SAI, ocean iron fertilization) were rejected due to their perceived irreversibility once deployed.

Second, 'ingenious attempt' was underpinned by techno-optimism with sentiments of hope, exhilaration, and enthusiasm. The words "fun," "amazing," and "interesting" were uttered by some—particularly male—participants (G1, 2, 4). Participants seemed to have a strong belief in human ingenuity and technological progress; technology was positively articulated as bringing better human life. Developing grand-scale technology was acclaimed as a sign of *innovativeness* (G6). In contrast to 'frightening idea,' the idea of artificial manipulation was not necessarily seen as bad or hubristic; instead, it was considered a human responsibility to restore harmony with nature (cf. Wong, 2015). However, there were mixed feelings about techno-fixing the climate through geoengineering: participants saw it as *necessary* because of man-made environmental disruption, but, at the same time, considered it as *undesirable* due to unknown consequences.

Third, there was a prevailing reaction among many participants to see geoengineering as an 'implausible plan' or 'pie in the sky.' Participants embraced deep skepticism of the plausibility that geoengineering could be a real policy option. Geoengineering was seen as technically unfeasible or *unrealistic*, akin to science fiction; in particular, the idea of space mirror was mocked in several groups (G1, 2, 3, 5). Geoengineering was also considered to be politically impracticable or *ungovernable*, given current political circumstances, with numerous conflicts among nations; the participants were doubtful of the possibility that nations around the world could cooperate to regulate it together. Furthermore, the participants surmised that it would involve enormous time and cost to develop geoengineering technology, and therefore it could not be realized in the near future (G2, 3, 4, 6).

Finally, geoengineering was articulated as an 'unnecessary solution' in some groups (G3, 5, 6). This framing has a twofold meaning. On one hand, a few participants (G3, 6) conjectured that humans would eventually adapt to the warmer planet, and thus it would be *unnecessary* to use geoengineering. On the other hand, some people (G5, 6) fiercely criticized geoengineering as a misguided idea because it addresses only the symptoms rather than the causes of the problem of climate change, i.e., increased greenhouse gas emissions (cf. Wibeck et al., 2015). Therefore, the use of geoengineering was seen as *unsuitable* or a 'smoke screen' to maintain business as usual; they considered changing wasteful modern lifestyles to be the fundamental solution to climate change.

4.1.2. Situating geoengineering in climate change responses

Emergency framing had a significant impact on the participants' discussion, changing the atmosphere of conversations and infusing a sense of urgency about the climate crisis; for example, in Group 5 there was a moment of silence in which no one could express themselves probably owing to the shocked feelings about 'climate emergency.' Of course, there were a few skeptical reactions to the emergency framing, either saying that the emergency is not a fact but is an opinion of scientists (G1) or claiming that the earth is so resilient that the emergency wouldn't take place (G4).

When asked about how we should address climate change and evaluate the role of geoengineering, two broad discourses emerged: (1) 'mitigation first!' and (2) 'all options on the table.' The 'mitigation first!' discourse is unambiguous in emphasizing first and foremost the importance of mitigation; participants in all groups largely saw mitigation as an orthodox approach to the climate problem. However, their judgments of geoengineering were ambivalent. Geoengineering was commonly considered as an unviable or unthinkable option for addressing climate change, but there were different degrees of opinion, from a few (G3, 6) unconditionally rejecting the whole concept of geoengineering to some (G2, 3, 4, 5, 6) *reluctantly* accepting research into geoengineering but refusing to say yes to its use as a potential last-ditch measure.

In the 'all options on the table' discourse, participants in all groups more or less agreed that all approaches (mitigation, adaptation, geoengineering) are needed to avoid dangerous climate change. That is to say, people's views were unambiguous in avoiding the climate crisis by any means possible; however, their views on mitigation were ambiguous and divided between those prioritizing mitigation over other approaches and those embracing skepticism on mitigation, seen as politically ineffective or failed. Meanwhile, the views on geoengineering as a climate change response were varied too. Most people in all groups saw geoengineering as a backup or last resort to ward off 'climate emergency,' but didn't presume an automatic shift from research to deployment, whereas a few people (G5) strongly advocated its deployment due to their deep skepticism about successful mitigation. Importantly, within this discourse, people arrived at a near consensus to more *willingly* accept research into geoengineering, which means there was no ambivalence in their advocacy for 'more research'.

Taken together, the emergency framing substantially created the conditions for most, if not all, participants in all groups to accept—either willingly or reluctantly—the need for 'more research' on geoengineering (cf. Corner et al., 2011). But at the same time, the emergency framing diversified—and hence increased ambiguity of—the participants' views on how we should respond to climate change, either 'going with' mitigation (and adaptation) or 'going after' every possible means including geoengineering.

4.2. Understanding the proposal for SAI field trials

In the first part of the discussions, the participants' views on geoengineering experimentation converged into accepting the 'more research' argument; however, the proposal for SAI field trials had a *disruptive* effect on such a consensual view. When the subject shifted from the *abstract* geoengineering concept to the *concrete* SAI field trial, the virtual consensus among participants on the need for 'geoengineering research' was broken into more conflicted and contended views. Participants raised many social, political and ethical concerns over the SAI field trial and wrestled to understand its meanings in different dimensions. These dimensions can be broadly classified into four core themes, on which each subtheme commonly centered, but various perspectives were brought together: (1) *accountability*, (2) *controllability*, (3) *predictability*, and (4) *desirability*. In each dimension, there were tensions and inconsistencies in the ways that participants made sense of—and thereby gave meaning to—SAI field trials.

4.2.1. Accountability

Participants wrestled with understanding whether and how SAI field trials can be done in a democratically accountable way from two aspects: (1) *openness* (or *secrecy*), and (2) *engagement* (or *deference*). First, it was very clear that many participants in all groups strongly demanded transparency of SAI field trials. Full public disclosure of research plans and results (including negative ones) seemed like a precondition to consent for conducting outdoor experiments (cf. Rayner et al., 2013):

> "I want [the information on the experiment] to be made public before it starts ... there might be downsides to an experiment ... This information should be published without fail."
>
> [(Makoto, male, G6)]

The request for openness concerns not only what scientists do but also who they are and how they communicate with the lay public. A lack of lucidity was indeed considered as a major problem of communication with scientists:

> "I want [scientists] to clearly explain the significance and impact [of the experiment] ... I want to be better informed about these things rather than just accepting things as they are and remaining ignorant about what they are doing."
>
> [(Ai, female, G2)]

But participants also expressed concern over opacity. They were not sure to what extent scientists could ensure transparency, implying mistrust in scientists (and the government). In spite of a strong demand for transparency, some participants even suspected that SAI field trials might possibly be done behind closed doors:

> "Will [experiments] be done secretly? ... I just imagine they might be done secretly ... Will scientists really tell us what they are going to do?"
>
> [(Naomi, female, G3)]

Thus, participants were faced with a contradiction between their expectations for openness and their suspicions of secrecy. As one way to resolve this paradox, some participants suggested setting up an independent body tasked with monitoring research activities.

Second, the accountability discourse was contended in terms of the lay public's involvement in decision-making regarding SAI field trials. In all groups but Group 1, participants expressed great zeal for being engaged in decision-making in one way or another (e.g., a referendum) regardless of their opinions (pro or con) about the field experiment. But there was also mistrust of the established political authorities, i.e., that public engagement would result only in tokenism:

> "I would feel better about raising my voice if citizens' opinions were truly reflected ... but I don't think our voices matter ... perhaps the establishment will decide arbitrarily ... they won't listen to us."
>
> [(Yutaka, male, G6)]

Meanwhile, others more explicitly preferred expert judgment to public consultation:

> "It's better to entrust experts with technical issues ... it's often hard to reach an agreement with many people ... With clear procedures, we can only defer to their decisions regardless of whether they are right or wrong."
>
> [(Daisuke, male, G4)]

The reasons for deference to expert judgment were because of no interest (G1, 2) and/or no knowledge (G2, 4, 5) relevant to the topic per se. In short, there was skepticism about the capability and suitability of the lay public for making decisions on highly technical issues (cf. Wong, 2013).

While the need for public engagement was by and large endorsed, hesitation in public consultation (or preference for expert judgment) was also articulated, which turned into inconclusive debates over who—either lay citizens or experts—should make the final decision whether to do open-air experiments or not.

4.2.2. Controllability

The controllability of SAI field trials was disputed from three aspects: (1) *technical reversibility*, (2) *institutional controllability*, and (3) *spatial boundedness*. First, many participants in several groups (G2, 4, 5, 6) were very afraid of the technical irreversibility of outdoor experiments, which in turn raised concern over unknown consequences:

> "Once released, [particles] cannot be retrieved at all ... what kind of effects may be caused? ... I cannot say simply, 'Let's do experiments.'"
>
> [(Kazuko, female, G5)]

The technical characteristics of SAI heightened participants' apprehensions about irreparableness in case that unanticipated situations may happen. This perceived irreversibility often led to disapproval of SAI field trials. Meanwhile, there were a few reactions that saw field experiments as temporary (not permanent), and thus acceptable:

> "Experiments should be banned if they have a lasting effect but ... it's temporary ... we don't have much of a choice ... Experiments need to move ahead."
>
> [(Shota, male, G1)]

Second, participants speculated on various political and institutional challenges to govern SAI field trials. One exemplary case was a tension in understanding the slippery-slope argument. Some participants (G1, 2, 4, 6) bluntly said that the slippery-slope scenario is unlikely, because it is unreasonable to move on to large-scale experiments unless small-scale tests could confirm safety. Others, however, approved the slippery-slope argument, irrespective of the confirmation of safety (G2, 3, 4, 5). Their anxieties were in some way related to concern over vested interests (cf. Long and Scott, 2013). Participants worried especially about the influence of financial interests when private corporations are involved in research activities:

> "When financed [by corporations], it may be the case that information beneficial only to sponsors will be published ... That scares me the most ... Even if there are negative consequences, we may be told there is no problem."
>
> [(Sachiko, female, G5)]

To prevent vested interests from creating a "socio-technical lock-in" (Cairns, 2014), many participants in all groups agreed that some sort of institutional framework is necessary to independently oversee and regulate field experiments. They also distinctly preferred an international mechanism to prevent unilateral experimentation by other nations, but remained uncertain about whether such an institution could be established.

Last but not least, the controllability discourse was dealt with from a geographical point of view. In this aspect, participants were broadly divided into two groups: those who believed field trials could be spatially delimited, and those who didn't. For the former, small-scale tests would be acceptable if done far from where they lived:

> "Why not do [experiments] in an uninhabited island? ... Not above my backyard ... It's better to start first at some place isolated from humans."
>
> [(Tomoko, female, G3)]

In this perspective, it was taken for granted that small- and large-scale experiments can be separated; therefore, gradual expansion from small to large was seen as a pragmatic approach. Others claimed that there is no such a thing as a spatially separable open-air experiment:

> "Even though [particles] were released over uninhabited land, with the earth's rotation ... We don't know what might happen ... I think it's uncontrollable."
>
> [(Yutaka, male, G6)]

For them, there is no clear boundary between small and large; if a field experiment is done, its effect will be necessarily global regardless of its scale. Thus the available options seemed like either 'all' (going outdoors) or 'nothing' (staying indoors).

4.2.3. Predictability

The predictability of SAI field trials was also intensively debated and articulated in multiple ways. Many participants in all groups admitted that computer simulations (in silico experiments) alone are insufficient; therefore, field trials (in situ experiments) seemed indispensable:

> "It is better to do outdoor experiments. We cannot know everything from the model calculation ... We'll never know if unanticipated situations may happen or not unless we do [outdoor] experiments."
>
> [(Kenichi, male, G4)]

Participants embraced the idea of 'learning by experimenting,' i.e., we could increase our knowledge (or reduce our ignorance) through field experiments, which would pave the way for both rejection *and* acceptance of SAI deployment. One elderly male (G6) who flatly defied the concept of SAI actually advocated its field trials so as to discard its deployment. Because of—not despite—uncertainty, the controlled and small-scale in situ experiment in the sky was justified to complement the in silico experiment in computer modeling.

However, uncertainty also rhetorically functioned to direct participants to suspect the validity of field trials. Whether small-scale tests really involve 'little or no' environmental impact attracted particular attention among many participants. One young female (G2) did not problematize its denotation of the term 'little or no'—she literally accepted what was said. But most of the other participants interpreted this as 'not a little or some' impact. Together with mistrust of scientists, indeterminacy of the phrase 'little or no' became a source of unrest:

> "It's said there is 'little or no' impact on the environment, but we cannot be sure unless we actually do [experiments] ... Is it really 'little or no'? We don't know. Maybe [scientists] are saying 'little or no' because they are afraid of opposition if they said 'there will be a little [impact],' aren't they? I may be too suspicious but it's conceivable."
>
> [(Megumi, female, G3)]

For some participants, uncertainty about the side effects of SAI field trials appeared to be the so-called 'unknown unknowns,' and thereby evoked irreducible fears. Because of this fear of unknown unknowns, 'zero risk' was strongly and *paradoxically* demanded.[5] The demand for 'zero risk' or 'absolute safety' was indeed paramount

[5] In this respect, as van Asselt and Vos (2008) noted, 'zero risk' is equated with 'zero uncertainty.'

among many participants in several groups (G1, 2, 3, 5). In particular, posing no risk to human health was seen as a non-negotiable precondition for consent to field trials:

> "We can investigate in labs whether [SAI] would harm human health ... If we can confirm its safety, then I think there will be no problem to do [outdoor experiments]."
>
> [(Chihiro, female, G1)]

Also, apprehensions about negative effects on human health were implicitly articulated as expectations on scientists, i.e., that scientists themselves should be somewhat like 'guinea pigs':

> "I want [scientists] to [research] what they want in their own backyards ... By doing so, their research can be useful to everyone."
>
> [(Ryo, male, G2)]

It is important to note that the issue of health impact was not introduced by the moderator, but was spontaneously brought out by participants.

Thus, SAI field trials were expected to be a means to reduce uncertainty, but at the same time was articulated as a source of uncertainty. It appeared to be indeterminable for participants to give a simple yes-or-no answer to SAI field trials, except for one middle-aged man who firmly rejected the whole concept of SAI:

> "There is no need for research because we already know [SAI] will cause negative impacts [on the environment] ... This is a bad idea, it's all too clear. We'd better find the alternatives."
>
> [(Jun, male, G4)]

What is important here is not that he categorically rejected SAI research as a whole but that he had a decisive answer; there was no room for ambivalence in his own decision.

4.2.4. Desirability

Is conducting SAI field trials desirable or undesirable? This question is related not only to the validity and necessity of field trials but also, and much more so, to the underlying basic concepts behind SAI. Participants contested the issue of desirability from two aspects: (1) human–nature relations, and (2) climate change responses. First, the notion of 'tampering with nature' was discussed from very divergent perspectives. Some participants dismissed this notion simply as a hubristic attitude of mastery over nature:

> "I'm against [SAI] from the beginning. Humans should not attempt to control the environment ... some kinds of technologies had better be forbidden."
>
> [(Hiroshi, male, G6)]

For them, leaving nature 'natural' is indeed virtuous and wise. In sharp contrast, a few male participants (G2, 3, 4) rejected this claim of hubris wholly by referring to it as "unscientific," "religious," "emotional," or "baseless." Some others rebutted the hubris argument as hypocrisy, neglecting the fact of man-made climate predicament:

> "We have been already altering [the climate] ... If you say [don't tamper with nature], then you have to stop breathing! ... Humans have been wearing down the planet, that's why we have this problem [i.e., climate change] now. And yet, saying don't tamper with what we've broken down, it sounds a bit ridiculous."
>
> [(Kaori, female, G1)]

Under the 'climate emergency' scenarios, the 'let-nature-take-its-course' approach was perceived as immoral, undesirable, or at least impracticable to keep the planet as a safe place for humanity. 'Tampering with nature' was then deemed a human responsibility, rather than hubris, i.e., a morally preferable way to fix the (broken) climate or restore harmony with nature (cf. Wong, 2015). Others were, however, stuck with ambivalence between two polarized views, unable to choose which course of action was better or the 'lesser of two evils':

> "As you said, [manipulating the climate] for human convenience is not good, but those who want to do experiments are also working hard to do something good, so neither is wrong. But then human beings are not the master of nature. [If we manipulate the climate] for human convenience ... then it might get us into a mess ... I just hope we can find the better alternatives."
>
> [(Megumi, female, G3)]

Importantly, concern over 'tampering with nature' was coupled with anxiety about unknown consequences, which in turn led people into passively wishing for alternative solutions, if any. Besides, it is also worth noting that a few people in Group 2 actually perceived SAI as a 'natural' process rather than an 'unnatural' intervention into the climate, picking up on the analogy of volcanic eruption, which in turn elicited their favorable views on SAI.

Second, the desirability discourse was articulated from broader perspectives on climate change responses. For example, pursuing SAI field trials was considered as somewhat serving intergenerational justice:

> "What about those yet to be born? ... If we think about those who will be born on the planet which can no longer be sustained, it's important to start doing something ... So, I'm rather for continuing experiments."
>
> [(Naoki, male, G1)]

SAI was not unconditionally upheld, but even so it was expected as one of the potential options (e.g., "second-best way") to cope with climate change in the long run. Thus, starting field trials *now* seemed like a prudent decision (cf. Gardiner, 2010). On the other hand, some participants (G4, 5, 6) were anxious about the odds that SAI may worsen the current climate predicament. A few others (G1, 6) condemned SAI as a shortsighted, reckless idea, primarily because it has nothing to do with reducing CO_2 emissions. For this reason, developing CDR technologies instead was seen as more desirable:

> "We'd better find the alternatives ... it's better to put forward research on sucking CO_2 ... We need to suck [CO_2 from the air] since it has been already released ... We'd better research this."
>
> [(Sachiko, female, G5)]

Above all, whether conducting SAI field trials is desirable or not seemed like an unsolvable puzzle. It was nearly impossible to obtain a decisive answer, especially when the question was framed in the context of 'climate emergency.'

5. Discussion and conclusions

This study examined how the meanings of geoengineering experimentation, particularly SAI field trials, were articulated and reconfigured in the deliberation of Japanese lay citizens. Our findings illuminated some clear dispositions of public views on geoengineering experimentation. First, the 'climate emergency' framing arguably compelled most participants to accept—either willingly or reluctantly—the argument for 'more research.' Previous literature has criticized the emergency framing as problematic, not only because 'climate emergency' is scientifically indeterminable but also because such framing itself is indeed politically dangerous, preemptively closing down democratic debate (Hulme, 2014; Markusson et al., 2014; Asayama, 2015; Horton, 2015; Sillmann et al., 2015). Likewise, our results showed that the emergency framing is an unhelpful and precarious way to communicate with the lay public, because it will lead them into a unipolar view in which geoengineering is justified as a last resort to avoid 'climate emergency,' and hence 'more research' on geoengineering emerges as the only way forward.

Second, when confronted with scientists calling for starting SAI field trials, participants spelled out some *unambiguous* preconditions for their consent: for example, the disclosure of all relevant information, including negative results, in plain language; setting up an independent (possibly international) assessment body to expel vested private interests; public engagement in decision-making process (but inconclusive on who should make a final decision); and the safety-first protocol of experimentation. In short, participants more or less endorsed the 'Oxford Principles' for governing geoengineering research (Rayner et al., 2013).

However, what is more remarkable in our findings is that public discourse on geoengineering experimentation was *ambiguous* and *ambivalent*, involving many inconsistencies and indeterminacies in understanding what geoengineering experimentation is and can do for our climate and society. When participants first encountered the idea of geoengineering, divergent affective reactions were evoked, from hopes and fears, to optimism and pessimism to enthusiasm and skepticism. These sentiments were polarized and divisive, pitting people against one another. The emergency framing, however, created a rather ambiguous climate of opinions among participants about how to respond to climate change, either prioritizing mitigation (and adaptation) or keeping all options open, including geoengineering. It also brought about participants' unambiguous *but* ambivalent consensus on the need for geoengineering research. Most (except a few) participants drew an unambiguous conclusion that 'more research' is needed to arm against the potential 'climate emergency' but still embraced ambivalence toward stepping into engineering the climate—some only reluctantly supported 'more research' and thus never considered geoengineering as a viable option, others more willingly admitted the need for 'more research' but remained cautious and undecided about its actual usage, as supposing a separation of research from deployment.

When the issue of SAI field trials was brought to the fore in the discussions, the virtual consensus of participants on the 'more research' argument was disrupted into far more ambiguous and ambivalent views. As mentioned above, the adequacy and validity of conducting SAI field trials was contested in different dimensions, namely, accountability, controllability, predictability, and desirability. In each dimension, there were both tensions and dilemmas in understanding what field experiment is for and about. For example, while people required a high degree of transparency of research activities, they were at the same time paradoxically captured by suspicion of secretive experimentation (accountability). People's perceptions of the artificial manipulation of the earth's climate were divided between hubristic attempt and responsible course of action (desirability). Furthermore, these dimensions are not mutually exclusive, but rather are inextricably intertwined with one another. The demand for 'zero risk,' for example, stemmed primarily from the fear of uncertain risks pertaining to field trials (predictability) but also was related to mistrust of scientists (accountability) and to concern over irreparable damage (controllability). This multidimensionality of discourses around SAI field trials indicates the immense difficulty of unfolding the complex web of diverse perspectives and of coming to terms with competing meanings.

Thus, the public discourse on geoengineering experimentation can be characterized by both *multivalence* and *ambivalence*. Cairns and Stirling (2014, p. 33) referred to multivalence as the "coexistence of multiple divergent normative positions within the debate," and to ambivalence as a simple binary of pros versus cons. However, our findings illustrate that multivalence and ambivalence can be seen as, respectively, *contention* and *indeterminacy* among multiple divergent normative positions. There were arguably visible clashes of different worldviews or imaginaries of geoengineering experimentation (multivalence); meanwhile people became profoundly undecided or undeterminable about having one's own decisive normative position on geoengineering experimentation when faced with diverse conceptions of it (ambivalence).

What, then, can our findings imply for wider public deliberation on geoengineering experimentation? First, we need more clarity when we talk about the need for 'more research' on geoengineering. Some scholars have suggested abandoning the term 'geoengineering' because of its fuzziness and creating a new categorization of climate change responses (Heyward, 2013; Boucher et al., 2014; Pereira, 2016). Similarly, the term 'geoengineering research' is so vague and unclear that it does not help the lay public to understand what it really means. Scientists should be cautious not to use such a blanket term because it indiscriminately conflates heterogeneous research—from computer modeling to field experiments—into a single, vaguely labeled category. This leaves the lay public ignorant about the issue at stake. Under such conditions, even if there is extensive public support for 'more research' on geoengineering, this is nothing but pseudo-acceptance (cf. Malone et al., 2010). Our findings demonstrated that the specificity of the SAI field trial as a *discursive* object actually served to open up—rather than close down—a space for diverse perspectives to be brought into the geoengineering debate (cf. Stirling, 2008). The precision of the term 'geoengineering research' is needed to facilitate inclusive and pluralistic debates on geoengineering experimentation and not to preemptively arrive at a consensus that 'we need more research.'

Yet, we should bear in mind that such attempts to disaggregate the term and to deliberate on the specific proposals of geoengineering experiment might also serve to prematurely close down the decision context and create a lock-in to particular options at the expense of alternative, otherwise possible, future pathways (Bellamy et al., 2013). In fact, a deliberate effort of public engagement with geoengineering could play a *performative* role: normalizing and reifying this speculative technological imaginary as a real policy option (Bellamy and Lezaun, 2015). So, the crucial question that we should ask ourselves is: When is the right time to move into public dialogue on the SAI field trial? If it is not now, when should we start *talking* about the SAI field trial before it actually starts?

Second, the SAI field trial is fundamentally different from computer modeling, indicating a symbolic shift to 'real-world' experimentation (Gross, 2016), where the boundary between research and deployment would be unclear. Although our results showed conflict among the participants in understanding whether research and deployment (or small and large) are separable or not, it was clear that the participants raised many social, political, and ethical concerns over SAI field trials. This signifies that the SAI field trial should be seen as a *social experiment*, where the realms of science and society are indistinguishable as part of an experimental system, and where its social and political consequences are inherently unknowable and uncontrollable (Stilgoe, 2016).

Meanwhile, indoor research on geoengineering such as computer modeling has been undertaken at present. Under current circumstances, this strand of research activities is considered as 'mundane' science and unlikely to be ceased or slowed down. And now, in the wake of the Paris Agreement, the call for starting SAI field trials by scientists seems to become stronger than ever before (e.g. Nature Geoscience, 2016). We can, therefore, anticipate the scenario that an open-air experiment of SAI would, despite controversy, take place at some point in the near future, and once it gets under way, there would be an attempt to normalize and reclassify it from 'controversial' to 'mundane' science. However, such an attempt at detaching science from politics is problematic not only because it will cultivate an illusion of 'pure-science' experiment but also because it could breed public distrust in science at large. Whether the SAI field trial will actually take place or not, if seen as a social experiment, the *purpose* of experiment matters for the legitimacy of science, and thus should be thoroughly discussed in the public (cf. Stilgoe et al., 2013b).

Finally, the ambivalence and ambiguity of public discourse around geoengineering experimentation is profound and deeply embedded in our worldviews (Macnaghten and Szerszynski, 2013; Rayner, 2015). The motivation behind the advocacy for SAI field trials was scientists' underlying assumption that 'more research' can lead, through 'more knowledge,' to 'wiser decisions.' The field experiment may possibly reduce to some extent uncertainty over the risks and benefits of SAI, but it certainly cannot reduce people's ambivalence about SAI, precisely because ambivalence is a *normative* (and *epistemological*) question, hence incalculable and incommensurable, unlike risks-benefits. As Cairns and Stirling (2014) noted, ambivalence seems to be pervasive and persistent, not something we can wipe out by 'more research.' Thus, instead of ignoring or repressing it, we should embrace ambivalence about both the pros and cons of geoengineering experimentation. This means, practically, that both proponents and opponents should be open to dissident voices and direct themselves to fostering reflexivity to critically analyze their own assumptions, premises, and cultural biases (cf. Bellamy, 2016). By doing so, we may be able to keep the geoengineering debate democratically accountable and socially inclusive, extending beyond the false dichotomy of 'for-or-against'.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.geoforum.2017.01.012.

References

Anshelm, J., Hansson, A., 2014a. Battling Promethean dreams and Trojan horses: Revealing the critical discourses of geoengineering. Energy Res. Soc. Sci. 2, 135–144. http://dx.doi.org/10.1016/j.erss.2014.04.001.

Anshelm, J., Hansson, A., 2014b. The last chance to save the planet? An analysis of the geoengineering advocacy discourse in the public debate. Environ. Humanit. 5, 101–123.

Asayama, S., 2015. Catastrophism toward "opening up" or "closing down"? Going beyond the apocalyptic future and geoengineering. Curr. Sociol. 63, 89–93. http://dx.doi.org/10.1177/0011392114559849.

Barbour, R., Kitzinger, J. (Eds.), 1999. Developing Focus Group Research: Politics, Theory and Practice. Sage, London.

Barrett, S., 2008. The incredible economics of geoengineering. Environ. Resour. Econ. 39, 45–54. http://dx.doi.org/10.1007/s10640-007-9174-8.

Beck, S., 2010. Moving beyond the linear model of expertise? IPCC and the test of adaptation. Reg. Environ. Change 11, 297–306. http://dx.doi.org/10.1007/s10113-010-0136-2.

Bellamy, R., 2016. A sociotechnical framework for governing climate engineering. Sci. Technol. Human Values 41, 135–162. http://dx.doi.org/10.1177/0162243915591855.

Bellamy, R., Chilvers, J., Vaughan, N.E., Lenton, T.M., 2012. A review of climate geoengineering appraisals. Wiley Interdiscip. Rev. Clim. Change 3, 597–615. http://dx.doi.org/10.1002/wcc.197.

Bellamy, R., Chilvers, J., Vaughan, N.E., Lenton, T.M., 2013. "Opening up" geoengineering appraisal: Multi-Criteria Mapping of options for tackling climate change. Glob. Environ. Change 23, 926–937. http://dx.doi.org/10.1016/j.gloenvcha.2013.07.011.

Bellamy, R., Lezaun, J., 2015. Crafting a public for geoengineering. Public Underst. Sci. http://dx.doi.org/10.1177/0963662515600965.

Blackstock, J.J., Battisti, D.S., Caldeira, K., Eardley, D.M., Katz, J.I., Keith, D.W., Patrinos, A.A.N., Schrag, D.P., Socolow, R.H., Koonin, S.E., 2009. Climate Engineering Responses to Climate Emergencies. Novim, Santa Barbara. <http://arxiv.org/pdf/0907.5140>.

Blackstock, J.J., Long, J.C.S., 2010. The politics of geoengineering. Science 327, 527.

Bloor, M., Frankland, J., Thomas, M., Robson, K., 2001. Focus Groups in Social Research. Sage, London.

Boucher, O., Forster, P.M., Gruber, N., Ha-Duong, M., Lawrence, M.G., Lenton, T.M., Maas, A., Vaughan, N.E., 2014. Rethinking climate engineering categorization in the context of climate change mitigation and adaptation. Wiley Interdiscip. Rev. Clim. Change 5, 23–35. http://dx.doi.org/10.1002/wcc.261.

Cairns, R., 2014. Climate geoengineering: Issues of path-dependence and socio-technical lock-in. Wiley Interdiscip. Rev. Clim. Change 5, 649–661. http://dx.doi.org/10.1002/wcc.296.

Cairns, R., Stirling, A., 2014. "Maintaining planetary systems" or "concentrating global power?" High stakes in contending framings of climate geoengineering. Glob. Environ. Change 28, 25–38. http://dx.doi.org/10.1016/j.gloenvcha.2014.04.005.

Caldeira, K., Keith, D.W., 2010. The need for climate engineering research. Issues Sci. Technol. Fall, 57–62.

Carr, W.A., Preston, C.J., Yung, L., Szerszynski, B., Keith, D.W., Mercer, A.M., 2013. Public engagement on solar radiation management and why it needs to happen now. Clim. Change 121, 567–577. http://dx.doi.org/10.1007/s10584-013-0763-y.

Cho, A., 2016. To fight global warming, Senate calls for study of making Earth reflect more light. Science. <http://www.sciencemag.org/news/2016/04/fight-global-warming-senate-calls-study-making-earth-reflect-more-light>.

Cicerone, R.J., 2006. Geoengineering: Encouraging research and overseeing implementation. Clim. Change 77, 221–226. http://dx.doi.org/10.1007/s10584-006-9102-x.

Corner, A., Parkhill, K., Pidgeon, N., 2011. "Experiment Earth?" Reflections on a public dialogue on geoengineering. Understanding Risk Working Paper 11–02. School of Psychology, Cardiff University, Cardiff. <http://psych.cf.ac.uk/understandingrisk/docs/experiment_earth.pdf>.

Corner, A., Parkhill, K., Pidgeon, N., Vaughan, N.E., 2013. Messing with nature? Exploring public perceptions of geoengineering in the UK. Glob. Environ. Change 23, 938–947. http://dx.doi.org/10.1016/j.gloenvcha.2013.06.002.

Corner, A., Pidgeon, N., 2015. Like artificial trees? The effect of framing by natural analogy on public perceptions of geoengineering. Clim. Change 130, 425–438. http://dx.doi.org/10.1007/s10584-014-1148-6.

Corner, A., Pidgeon, N., Parkhill, K., 2012. Perceptions of geoengineering: Public attitudes, stakeholder perspectives, and the challenge of "upstream" engagement. Wiley Interdiscip. Rev. Clim. Change 3, 451–466. http://dx.doi.org/10.1002/wcc.176.

Dilling, L., Hauser, R., 2013. Governing geoengineering research: Why, when and how? Clim. Change 121, 553–565. http://dx.doi.org/10.1007/s10584-013-0835-z.

Dykema, J.A., Keith, D.W., Anderson, J.G., Weisenstein, D., 2014. Stratospheric controlled perturbation experiment: A small-scale experiment to improve understanding of the risks of solar geoengineering. Philos. Trans. Roy. Soc. A 372, 20140059.

Fadeel, B., Karlsson, H.L., Bhattacharya, K., 2013. Geoengineering: Perilous particles. Science 340, 548–549. http://dx.doi.org/10.1126/science.340.6132.548-b.

Flannery, T., 2015. Atmosphere of Hope: Searching for Solutions to the Climate Crisis. Text Publishing, Melbourne.

Funtowicz, S., Ravetz, J.R., 1993. Science for the post-normal age. Futures 25, 739–755.

Gardiner, S.M., 2010. Is "arming the future" with geoengineering really the lesser evil? Some doubts about the ethics of intentionally manipulating the climate system. In: Gardiner, S.M., Caney, S., Jamieson, D., Shue, H. (Eds.), Climate Ethics: Essential Readings. Oxford University Press, Oxford, pp. 284–312.

Gross, M., 2016. Give me an experiment and I will raise a laboratory. Sci. Technol. Human Values 41, 613–634. http://dx.doi.org/10.1177/0162243915617005.

Hamilton, C., 2013. Earthmasters: The Dawn of the Age of Climate Engineering. Yale University Press, New Haven.

Hansson, A., 2014. Ambivalence in calculating the future: The case of re-engineering the world. J. Integr. Environ. Sci. 11, 125–142. http://dx.doi.org/10.1080/1943815X.2014.921629.

Heyward, C., 2013. Situating and abandoning geoengineering: A typology of five responses to dangerous climate change. PS Polit. Sci. Polit. 46, 23–27. http://dx.doi.org/10.1017/S1049096512001436.

Horton, J.B., 2015. The emergency framing of solar geoengineering: Time for a different approach. Anthr. Rev. 2, 147–151. http://dx.doi.org/10.1177/2053019615579922.

Hulme, M., 2012. Climate change: Climate engineering through stratospheric aerosol injection. Prog. Phys. Geogr. 36, 694–705. http://dx.doi.org/10.1177/0309133312456414.
Hulme, M., 2014. Can Science Fix Climate Change? A Case Against Climate Engineering. Polity Press, Cambridge.
Huttunen, S., Skytén, E., Hildén, M., 2015. Emerging policy perspectives on geoengineering: An international comparison. Anthr. Rev. 2, 14–32. http://dx.doi.org/10.1177/2053019614557958.
IPCC, 2012. Meeting Report of the Intergovernmental Panel on Climate Change – Expert Meeting on Geoengineering [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, C. Field, V. Barros, T.F. Stocker, Q. Dahe, J. Minx, K. Mach, G.-K. Plattner, S. Schlömer, G. Hansen, M. Mastrandrea (Eds.)]. IPCC Working Group III Technical Support Unit, Potsdam Institute for Climate Impact Research, Potsdam, Germany. <https://www.ipcc.ch/pdf/supporting-material/EM_GeoE_Meeting_Report_final.pdf>.
IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri RK, Meyer LA (Eds)]. IPCC, Geneva, Switzerland. <https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf>.
Irvine, P.J., Kravitz, B., Lawrence, M.G., Muri, H., 2016. An overview of the Earth system science of solar geoengineering. Wiley Interdiscip. Rev. Clim. Change 7, 815–833. http://dx.doi.org/10.1002/wcc.423.
Izrael, Y.A., Zakharov, V.M., Petrov, N.N., Ryaboshapko, A.G., Ivanov, V.N., Savchenko, A.V., Andreev, Y.V., Puzov, Y.A., Danelyan, B.G., Kulyapin, V.P., 2009. Field experiment on studying solar radiation passing through aerosol layers. Russ. Meteorol. Hydrol. 34, 265–273. http://dx.doi.org/10.3103/s106837390905001x.
Keith, D.W., 2013. A Case For Climate Engineering. MIT Press, Cambridge.
Keith, D.W., Duren, R., MacMartin, D.G., 2014. Field experiments on solar geoengineering: Report of a workshop exploring a representative research portfolio. Philos. Trans. Roy. Soc. A 372, 20140175.
Keith, D.W., Parson, E., Morgan, M.G., 2010. Research on global sun block needed now. Nature 463, 426–427. http://dx.doi.org/10.1038/463426a.
Kravitz, B., Caldeira, K., Boucher, O., Robock, A., Rasch, P.J., Alterskjær, K., Karam, D. B., Cole, J.N.S., Curry, C.L., Haywood, J.M., Irvine, P.J., Ji, D., Jones, A., Kristjánsson, J.E., Lunt, D.J., Moore, J.C., Niemeier, U., Schmidt, H., Schulz, M., Singh, B., Tilmes, S., Watanabe, S., Yang, S., Yoon, J.H., 2013a. Climate model response from the Geoengineering Model Intercomparison Project (GeoMIP). J. Geophys. Res. Atmos. 118, 8320–8332. http://dx.doi.org/10.1002/jgrd.50646.
Kravitz, B., Robock, A., Forster, P.M., Haywood, J.M., Lawrence, M.G., Schmidt, H., 2013b. An overview of the Geoengineering Model Intercomparison Project (GeoMIP). J. Geophys. Res. Atmos. 118, 13103–13107. http://dx.doi.org/10.1002/2013JD020569.
Linnér, B.-O., Wibeck, V., 2015. Dual high-stake emerging technologies: A review of the climate engineering research literature. Wiley Interdiscip. Rev. Clim. Change 6, 255–268. http://dx.doi.org/10.1002/wcc.333.
Long, J.C.S., Loy, F., Morgan, M.G., 2015. Start research on climate engineering. Nature 518, 29–31.
Long, J.C.S., Scott, D., 2013. Vested interests and geoengineering research. Issues Sci. Technol. Spring, 45–52.
Luokkanen, M., Huttunen, S., Hildén, M., 2014. Geoengineering, news media and metaphors: Framing the controversial. Public Underst. Sci. 23, 966–981. http://dx.doi.org/10.1177/0963662513475966.
Macnaghten, P., Szerszynski, B., 2013. Living the global social experiment: An analysis of public discourse on solar radiation management and its implications for governance. Glob. Environ. Change 23, 465–474. http://dx.doi.org/10.1016/j.gloenvcha.2012.12.008.
Malone, E.L., Dooley, J.J., Bradbury, J.A., 2010. Moving from misinformation derived from public attitude surveys on carbon dioxide capture and storage towards realistic stakeholder involvement. Int. J. Greenh. Gas Control 4, 419–425. http://dx.doi.org/10.1016/j.ijggc.2009.09.004.
Markusson, N., Ginn, F., Singh Ghaleigh, N., Scott, V., 2014. "In case of emergency press here": Framing geoengineering as a response to dangerous climate change. Wiley Interdiscip. Rev. Clim. Change 5, 281–290. http://dx.doi.org/10.1002/wcc.263.
Mcnutt, M., 2015. Ignorance is not an option. Science 347, 1293.
Mercer, A.M., Keith, D.W., Sharp, J.D., 2011. Public understanding of solar radiation management. Environ. Res. Lett. 6, 044006. http://dx.doi.org/10.1088/1748-9326/6/4/044006.
Merk, C., Pönitzsch, G., Kniebes, C., Rehdanz, K., Schmidt, U., 2015. Exploring public perceptions of stratospheric sulfate injection. Clim. Change 130, 299–312. http://dx.doi.org/10.1007/s10584-014-1317-7.
Morgan, M.G., Nordhaus, R.R., Gottlieb, P., 2013. Needed: Research guidelines for solar radiation management. Issues Sci. Technol. Spring, 37–44.
Moriyama, R., Sugiyama, M., Kurosawa, A., Masuda, K., Tsuzuki, K., Ishimoto, Y., 2016. The cost of stratospheric climate engineering revisited. Mitig. Adapt. Strateg. Glob. Change. http://dx.doi.org/10.1007/s11027-016-9723-y.
Nature Geoscience, 2016. Editorial: A step up for geoengineering. Nat. Geosci. 9, 855. http://dx.doi.org/10.1038/ngeo2858.
Nerlich, B., Jaspal, R., 2012. Metaphors we die by? Geoengineering, metaphors, and the argument from catastrophe. Metaphor Symb. 27, 131–147. http://dx.doi.org/10.1080/10926488.2012.665795.
NRC, 2015. Climate Intervention: Reflecting Sunlight to Cool Earth. The National Academies Press, Washington DC, USA.
Parker, A., 2014. Governing solar geoengineering research as it leaves the laboratory. Philos. Trans. Roy. Soc. A 372, 20140173.
Parson, E.A., Keith, D.W., 2013. End the deadlock on governance of geoengineering research. Science 339, 1278–1279. http://dx.doi.org/10.1126/science.1232527.
Pereira, J.C., 2016. Geoengineering, scientific community, and policymakers: A new proposal for the categorization of responses to anthropogenic climate change. SAGE Open 6. http://dx.doi.org/10.1177/2158244016628591.
Pidgeon, N., Parkhill, K., Corner, A., Vaughan, N., 2013. Deliberating stratospheric aerosols for climate geoengineering and the SPICE project. Nat. Clim. Change 3, 451–457. http://dx.doi.org/10.1038/nclimate1807.
Pielke Jr., R.A., 2007. The Honest Broker: Making Sense of Science in Policy and Politics. Cambridge University Press, Cambridge.
Rayner, S., 2015. To know or not to know: A note on ignorance as a rhetorical resource in geoengineering debates. In: Gross, M., McGoey, L. (Eds.), Routledge International Handbook of Ignorance Studies. Routledge, London and New York, pp. 308–317.
Rayner, S., Heyward, C., Kruger, T., Pidgeon, N., Redgwell, C., Savulescu, J., 2013. The Oxford principles. Clim. Change 121, 499–512. http://dx.doi.org/10.1007/s10584-012-0675-2.
Robock, A., 2008. 20 reasons why geoengineering may be a bad idea. Bull. Atmos. Sci. 64, 14–18. http://dx.doi.org/10.2968/064002006.
Robock, A., 2012. Is geoengineering research ethical? Peace Secur. 4, 226–229.
Robock, A., Bunzl, M., Kravitz, B., Stenchikov, G.L., 2010. A test for geoengineering? Science 327, 530–531. http://dx.doi.org/10.1126/science.1186237.
Robock, A., MacMartin, D.G., Duren, R., Christensen, M.W., 2013. Studying geoengineering with natural and anthropogenic analogs. Clim. Change 121, 445–458. http://dx.doi.org/10.1007/s10584-013-0777-5.
Royal Society, 2009. Geoengineering the Climate: Science, Governance and Uncertainty. Royal Society, London.
Schäfer, S., Irvine, P.J., Hubert, A.-M., Reichwein, D., Low, S., Stelzer, H., Maas, A., Lawrence, M.G., 2013. Field tests of solar climate engineering. Nat. Clim. Change 3. http://dx.doi.org/10.1038/nclimate1987. 766–766.
Scholte, S., Vasileiadou, E., Petersen, A.C., 2013. Opening up the societal debate on climate engineering: How newspaper frames are changing. J. Integr. Environ. Sci. 10, 1–16.
Sillmann, J., Lenton, T.M., Levermann, A., Ott, K., Hulme, M., Benduhn, F., Horton, J.B., 2015. Climate emergencies do not justify engineering the climate. Nat. Clim. Change 5, 290–292.
Stilgoe, J., 2015. Experiment Earth: Responsible Innovation in Geoengineering. Routledge, Earthscan, Oxon.
Stilgoe, J., 2016. Geoengineering as collective experimentation. Sci. Eng. Ethics 22, 851–869. http://dx.doi.org/10.1007/s11948-015-9646-0.
Stilgoe, J., Owen, R., Macnaghten, P., 2013a. Developing a framework for responsible innovation. Res. Policy 42, 1568–1580. http://dx.doi.org/10.1016/j.respol.2013.05.008.
Stilgoe, J., Watson, M., Kuo, K., 2013b. Public engagement with biotechnologies offers lessons for the governance of geoengineering research and beyond. PLoS Biol. 11, e1001707. http://dx.doi.org/10.1371/journal.pbio.1001707.
Stirling, A., 2007. Risk, precaution and science: Towards a more constructive policy debate. EMBO Rep. 8, 309–315.
Stirling, A., 2008. "Opening up" and "closing down": Power, participation, and pluralism in the social appraisal of technology. Sci. Technol. Human Values 33, 262–294. http://dx.doi.org/10.1177/0162243907311265.
Sugiyama, M., Asayama, S., Kosugi, T., Ishii, A., Emori, S., Adachi, J., Akimoto, K., Fujiwara, M., Hasegawa, T., Hibi, Y., Hirata, K., Ishii, T., Kaburagi, T., Kita, Y., Kobayashi, S., Kurosawa, A., Kuwata, M., Masuda, K., Mitsui, M., Miyata, T., Mizutani, H., Nakayama, S., Oyamada, K., Sashida, T., Sekiguchi, M., Takahashi, K., Takamura, Y., Taki, J., Taniguchi, T., Tezuka, H., Ueno, T., Watanabe, S., Watanabe, R., Yamagishi, N., Yoshizawa, G., 2017. Transdisciplinary co-design of scientific research agendas: 40 research questions for socially relevant climate engineering research. Sustain. Sci. 12, 31–44. http://dx.doi.org/10.1007/s11625-016-0376-2.
Sütterlin, B., Siegrist, M., 2016. Public perception of solar radiation management: The impact of information and evoked affect. J. Risk Res. http://dx.doi.org/10.1080/13669877.2016.1153501.
Svoboda, T., 2016. Aerosol geoengineering deployment and fairness. Environ. Values 25, 51–68. http://dx.doi.org/10.3197/096327115X14497392134883.
Szerszynski, B., Kearnes, M., Macnaghten, P., Owen, R., Stilgoe, J., 2013. Why solar radiation management geoengineering and democracy won't mix. Environ. Plan. A 45, 2809–2816. http://dx.doi.org/10.1068/a45649.
van Asselt, M., Vos, E., 2008. Wrestling with uncertain risks: EU regulation of GMOs and the uncertainty paradox. J. Risk Res. 11, 281–300. http://dx.doi.org/10.1080/13669870801990806.
Victor, D.G., Morgan, M.G., Apt, J., Steinbruner, J., Ricke, K., 2013. The truth about geoengineering: Science fiction and science fact. Foreign Aff. <https://www.foreignaffairs.com/articles/global-commons/2013-03-27/truth-about-geoengineering>.
Wibeck, V., Hansson, A., Anshelm, J., 2015. Questioning the technological fix to climate change: Lay sense-making of geoengineering in Sweden. Energy Res. Soc. Sci. 7, 23–30. http://dx.doi.org/10.1016/j.erss.2015.03.001.
Wong, P.-H., 2013. The public and geoengineering decision-making. Techné Res. Philos. Technol. 17, 350–367. http://dx.doi.org/10.5840/techne201421110.
Wong, P.-H., 2015. Confucian environmental ethics, climate engineering, and the "playing god" argument. Zygon 50, 28–41. http://dx.doi.org/10.1111/zygo.12151.
Wynne, B., 2001. Creating public alienation: Expert cultures of risk and ethics on GMOs. Sci. Cult. 10, 445–481. http://dx.doi.org/10.1080/09505430120093586.