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Perceptions of climate engineering in the South Pacific, Sub-Saharan Africa, and North American Arctic

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Abstract Nearly all research on public perceptions of climate engineering has been conducted in wealthy, developed countries. However, understanding perspectives from vulnerable populations is critical to inclusive, democratic debate on both research and governance. This study utilized in-depth interviews to explore the perspectives of vulnerable populations in the South Pacific, Sub-Saharan Africa, and the North American Arctic. Interviewees in this study were desperate for solutions to climate change and therefore willing to consider climate engineering. However, their willingness to consider climate engineering could be characterized as both deeply reluctant and highly conditional. Interviewees expressed a number of concerns about potential social and political implications of engineering the climate. They also described conditions that may need to be met to ensure that future climates (engineered or otherwise) are more equitable.

1 Introduction

Regions that are prone to harmful biophysical impacts from climate change also house some of the world's most vulnerable populations with the least capacity to adapt (IPCC 2014). Unfortunately, current international commitments to reducing greenhouse gas emissions are highly unlikely to prevent global warming in excess of 2 °C (Boyd et al. 2015). As a result, some scientists and policymakers have begun to advocate for serious consideration of climate engineering technologies (Crutzen 2006; Keith 2013). Proposals include both efforts to remove carbon dioxide from the atmosphere, often referred to as carbon dioxide removal (CDR), and efforts to increase the amount of sunlight reflected into space, referred to as solar radiation

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management (SRM). Some advocates for further research on the topic have suggested that there is a strong ethical case for advancing knowledge about climate engineering technologies if they might help the world's most vulnerable populations (Horton and Keith 2016; Keith 2017).

While early research suggests climate engineering could potentially reduce average global temperatures, it is far from certain that vulnerable populations would benefit from research or deployment of such technologies (Suarez and van Aalst 2017). Furthermore, several commentators have pointed out that it is problematic to characterize climate engineering as beneficial to vulnerable populations without actually consulting them (Flegal and Gupta 2017; Stilgoe 2015). This has prompted a number of calls for engagement with populations in developing countries, as well as with indigenous populations within developed countries (Cairns 2015; Preston 2012; Suarez et al. 2013; Whyte 2012).

This study draws on interviews conducted in the South Pacific, North American Arctic, and Sub-Saharan Africa to examine vulnerable populations' perspectives on climate engineering. The findings indicate concerns about potential social and political implications of engineering the climate, as well as conditions that may need to be met to ensure that future climates (engineered or otherwise) are more equitable. In line with previous research related to vulnerable populations' perspectives on climate (Farbotko and Lazrus 2012), we acknowledge our position as Western scholars and do not attempt to speak for the diverse individuals we interviewed. Rather, we tried to adopt a listening disposition and do our best here to bring interviewee perspectives into critical conversation with ongoing discussions about climate engineering.

2 Non-Western perspectives on climate engineering and technological vulnerability

Social science research on climate engineering has been conducted almost exclusively in wealthy, developed countries (for summaries and reviews of these studies see Burns et al. 2016; Corner et al. 2012). Few studies have examined the perspectives of vulnerable populations, despite claims that research in developing countries and with indigenous groups is "crucial" and "critical" (Washington Geoengineering Consortium 2013; Merk et al. 2015).

In the only peer-reviewed study focused specifically on perspectives from the Global South, Winickoff et al. (2015) found that African, South American, and Asian participants expressed concerns that the Global North would use climate engineering to deflect "moral responsibility" for its role in the climate problem. Participants also expressed concerns about scientists' levels of confidence in promoting climate engineering field experiments based largely on climate models, and wanted to see accountability and credible oversight established for the governance of even small-scale climate engineering experiments.

In one of the only studies that compares public views across a wide range of countries and cultures, Sugiyama et al. (2016) found more support for climate engineering among undergraduate students in China, India, and the Philippines as compared to Japan, Australia, and South Korea. The authors indicate that levels of support could be linked to higher levels of concern about climate change in developing countries.

Additional insights about the views of vulnerable populations come from reports resulting from a series of workshops. Participants in Solar Radiation Management Governance Initiative (SRMGI) workshops in three African countries indicated broad support for African involvement in research and governance, including public oversight, stakeholder engagement, and capacity building (AAS and SRMGI 2013). The report from these workshops concludes that

broader engagement of African perspectives is necessary to improve the chances that SRM research is handled with humility, wisdom, and prudence. A report from a similar event in the South Pacific indicates that participants thought climate engineering should not be a substitute for mitigation, regulations should be put in place to govern future research on climate engineering, and that Pacific Island nations should stress the moral and ethical aspects of climate engineering. They also expressed concerns about unintended consequences and unforeseen impacts, questions about who would govern climate engineering, and the importance of informed consent in the context of research (Beyerl and Maas 2014). Collectively, these sources suggest that far from viewing research on climate engineering as a moral requirement, vulnerable populations may harbor serious doubts about whether they will in fact benefit from further exploration of proposed technologies (Winickoff et al. 2015).

The perspectives documented above mirror in many ways broader critiques of the global dissemination of Western science and technology. Development studies and science and technology studies scholars have documented concerns about, indifference towards, and even rejection of Western innovations in developing countries arising from dissonance with social and political assumptions embedded in proposed technologies (Jasanoff and Wynne 1998; Leach et al. 2005). Embedded assumptions often consist of a particular vision of progress wherein Western science and technology serve as the cornerstones for solutions to global-scale problems, largely for the benefit of the global poor (Jasanoff 2005; Stilgoe 2015).

These assumptions disempower vulnerable populations by suggesting that the problems they face are beyond their control and require technologically advanced solutions from wealthy, developed nations (Farbotko and Lazrus 2012; Wynne 2005). Furthermore, the assumed global applicability of Western technologies also tends to overlook differences between vulnerable populations and the local contexts in which they encounter technologies. Focusing on technological solutions also often results in an emphasis on reducing physical risks through greater technological precision (Jasanoff 2005). This obscures the often more important ways in which vulnerability extends beyond physical impacts of new technologies and includes vulnerability to the inevitable social and political changes that result from their development and use (Leach et al. 2005). These critiques lie at the heart of calls for more inclusive discussions about climate engineering (Suarez et al. 2013). As Stilgoe (2015, p. 35) has argued, anticipating potential impacts of climate engineering, "does not depend on the strength of our crystal balls; it depends on whom we choose to talk and listen to." The study presented below was an attempt to expand the number of perspectives currently being "listened to" in ongoing discussions about climate engineering research and governance.

3 Methods

Research was conducted with vulnerable populations in regions currently experiencing disproportionate impacts from climate change (IPCC 2014; ND-GAIN 2014), populations who may also be vulnerable to physical, social, and/or political impacts of climate engineering technologies should they be developed and deployed (Moreno-Cruz et al. 2012; Suarez and van Aalst 2017). These regions included the South Pacific, North American Arctic, and Sub-Saharan Africa. Partnerships were developed with regional and local research institutions to select specific study sites in both urban and rural areas. Study sites included the capital city of Honiara and rural areas in the Western Province of the Solomon Islands, Anchorage and Barrow in Alaska, and the city of Nairobi and the Maasai Mara region of Kenya.

Because knowledge of climate engineering tends to be limited, interviews were conducted with individuals working on climate change or in a closely related field (such as agriculture, wildlife conservation, or ecotourism). Partner organizations helped identify potential interviewees. Every attempt was made to ensure diversity in terms of age, gender, socio-economic class, and type of involvement on climate related issues. A total of 89 interviews were conducted with 100 individuals from public, private, and not-for-profit sectors. This included 33 individuals in the Solomon Islands (13 women and 20 men), 29 Alaska Natives (14 women and 15 men), and 38 individuals in Kenya (11 women and 27 men). While considerable efforts were made to achieve gender balance, the sample has more men than women because, in both Kenya and the Solomon Islands, more men hold formal positions in these fields compared with women. While the bulk of interviews were conducted with individuals, some were conducted with two people. Interviewees ranged in age from early 20s to early 70s, with a similar age range in all three sites. Interviewees included high-level government officials, agricultural producers, hunters and fishermen, university and NGO scientists, ecotourism operators, administrators at regional scientific organizations, and staff members of local, national, and international NGOs. All interviews were conducted in English.

In-depth semi-structured interviews were utilized to develop an understanding of different perspectives on climate change and climate engineering. An interview guide consisting of open-ended questions was used in concert with numerous probes and follow-up questions to illicit detailed responses and enable comparability across interviews (Hesse-Biber and Leavy 2006; Rubin and Rubin 2005). Initial interview questions focused on participant views of climate change and possible responses. Interviewees were also asked whether or not they had heard of climate engineering and, if so, what they knew and thought about it.

Then a brief animated film (7:35 min in length) was shown introducing the topic of climate engineering. This film was an early version of a public education film produced by Climate Media Factory for the Institute for Advanced Sustainability Studies and used for research purposes with permission. The film indicated that scientists have begun researching climate engineering as a potential response to climate change, introduced the different branches of climate engineering (CDR and SRM), and highlighted two specific SRM approaches (marine cloud brightening and sulfate particle injection). The film also raised several social, political, and ethical questions.

After viewing the film, interviewees were asked about climate engineering, including what they thought about climate engineering as a potential response to climate change; their views on social, political, and ethical considerations; and ways to include vulnerable groups in climate engineering research and decision-making. The film and interview questions were pretested and thoroughly reviewed by experts on qualitative data collection and climate engineering. The film and subsequent questions focused on SRM, but interviewees sometimes discussed CDR techniques as well. The results presented below focus primarily on SRM because the scope and scale of potential impacts from those proposed technologies have generated greater social and political controversy.

Attempts at eliciting perspectives on unfamiliar, emergent technologies can present methodological challenges related to the framing of information provided (Cairns 2015; Corner et al. 2012). Previous research suggests different framings of climate engineering can evoke different responses. For example, framing climate engineering as analogous to natural processes (e.g., describing CDR techniques acting like “artificial trees”) appears to garner more support than standard scientific language (e.g., describing CDR as involving chemical processes and industrial machinery) (Corner and Pidgeon 2015). To address this challenge, we used a framing-for-deliberation approach (Friedman 2007; Walmsley 2009) to frame both the information presented to interviewees (including information in the film) as well as the

questions asked about climate engineering. This approach explicitly creates space for participants to express diverse opinions and draw on different forms of knowledge, through open-ended questions that attempt to avoid explicit framing of climate engineering.

All of the interviews were digitally recorded and professionally transcribed. Data analysis consisted of an iterative process of reading interview transcripts multiple times, coding transcripts through the identification of themes, writing analysis memos, and exploring relationships between the data and relevant literature and theory (Patterson and Williams 2002). Data excerpts from the interviews are presented below to both illustrate participant views and serve as evidence for conclusions.[1]

4 Results

Interviewees shared detailed and nuanced perspectives on climate engineering, even with low levels of prior awareness. Of the 100 interviewees, 87 had either never heard of climate engineering or knew little or nothing about it prior to being interviewed. Nine individuals (six in Kenya and three in Alaska) had encountered climate engineering in professional settings or popular media and were familiar with the basic premise. Four interviewees (two in Alaska and two in Kenya) had been exposed to the topic in academic settings, conferences, or workshops, and were knowledgeable about the general concept and some proposed technologies.

The results below detail the striking similarities in the views of vulnerable populations across the three different study sites. Despite considerable geographic, historical, political, and cultural differences, interviewees in the three sites had surprisingly similar perspectives on climate engineering. The findings explored in detail below focus on interviewees' high levels of concern about climate change impacts and desperation for solutions, deeply reluctant willingness to consider climate engineering, concerns about potential social and political implications, and conditions that would need to be met to address those concerns.

4.1 Climate change: local consequences and distant responsibility

Interviewees were asked for their thoughts on climate change and almost unanimously indicated that they were already experiencing it. Nearly every interviewee spoke at length about impacts that were already posing serious threats to lives and livelihoods in their part of the world. For instance, one Alaska Native subsistence hunter discussed the following impacts:

> For the subsistence users, the people who live off the land in rural Alaska, the biggest concern is the effect [climate change] has on the plants and animals that they rely on. … It's been tough on hunters. We used to go 60, 80 miles to get walrus, and now we're going sometimes 200 miles. The pattern of the ice has really changed. The thickness, the quality of ice, it's not the quality it used to be. Pulling up a boat on a piece of floating ice to butcher a walrus, it's not like it used to be. It's more dangerous.

Interviewees from all three regions emphasized the economic, social, and cultural toll of these impacts. Another subsistence hunter in Alaska explained how the loss of sea ice, in addition to affecting food supplies, was disrupting intergenerational relationships and knowledge transfer.

[1] Of the block quotes below, 46% are from interviewees in Alaska, 33% from Kenya, and 21% from the Solomon Islands.

> When I was growing up the ice never used to leave. … That gave us more opportunities to teach our younger men how to hunt on the ice. But within the last 15 to 20 years, with global warming, the ice leaves our shore in the early part of July…When the ice is not there, the opportunity to bond and be with the young men at a critical time is gone—especially during those younger teenage years where they learn so much. The lost opportunity to associate out on the ice because of global warming really affects how young men are learning about the environment and the dangers of the ice.

While the impacts of climate change were tangible and local, the majority of interviewees across all three study sites assigned blame and responsibility to distant, powerful interests. One interviewee form Kenya suggested that "developed countries are not showing commitment towards tackling this problem," the kind of commitment required by a "moral conscience." Many Alaska Natives expressed frustration that powerful economic and political interests in other parts of the USA were preventing meaningful action on climate change while indigenous populations bore the brunt of impacts.

The notion that "we are not causing the problem; they are causing the problem" colored views on climate engineering as a potential solution to climate change. For instance, when asked what his preferred solution to climate change would be, one Solomon Islander responded:

> Number one, Americans stop their greed … I just ask America and China and India … to stop creating those emissions. I think that is my call for all the big countries. Because we in the Solomon Islands … produce very little, probably not a very significant level of emission or sequestration of carbon.

Many interviewees wanted to see major emitters step up and take responsibility for causing climate change, and were angered that they were being harmed by a problem that they did not create. Furthermore, interviewees indicated that they were working very hard to adapt and mitigate where possible, but that they ultimately felt helpless to solve the problem. As such, one of the most frustrating aspects of climate change for many interviewees was a sense of dependence upon others to prevent future harm.

4.2 Deeply reluctant acceptance

Due to their concerns about climate change impacts and frustration with what they viewed as lackluster mitigation efforts, the majority of interviewees across all three sites indicated they were willing to consider climate engineering. In fact many interviewees felt that they did not have a choice at this point, as poignantly described by this interviewee from Alaska:

> Due to the devastation that's occurring with climate change already, that we see here, we have to look at other means. With the delays that we've had with our national will to decrease carbon emissions, that's the reality of where we are.

While interviewees were willing to consider options beyond mitigation and adaptation, they were far from thrilled at the need to consider climate engineering—or as the interviewee quoted above went on to say, "I am reluctant, but accepting." In fact, while a handful of interviewees in all three sites were either enthusiastic about climate engineering or completely rejected the idea, the majority expressed what could be characterized as 'reluctant acceptance.'

This reluctant acceptance consisted of a willingness to consider any alternatives being put forward based on deep-seated concerns about climate change. As one interviewee from Kenya put it "If there is a possibility that mitigation and adaptation might fail in the long term, I think I'm open to thinking about how else can we do it." Another interviewee from Alaska initially thought that climate engineering was "idiotic" and "arrogant," but then changed her mind because she believed that we "have to come up with something."

However, reluctant acceptance was far from support for further research. Rather, interviewees simultaneously expressed sincere reservations and concerns. One interviewee who frequently facilitated conversations with Alaska Natives around science, policy, and environmental issues said:

> It's hard to dwell on the negative for me, because we do a lot of work around strength, assets, and empowerment. As I've been talking and sharing my concerns and kind of doing what we call in our work the "primal scream" … We actually make room for it in our dialogues, because it's human nature. It's not a judgment … we just know that if we don't give people room to air their concerns, the risks that they perceive or have experienced, we'll never really get full buy-in on the solution.

As the term "primal scream" implies, expressions of concern may involve strong visceral reactions to climate engineering, and there is value in making space for people to express those reactions. Initial reactions are often rooted in past experiences and not acknowledging them could prevent meaningful dialog about whether and how various concerns could be addressed. The remaining results sections explore interviewee concerns about climate engineering and how they wanted to see them addressed.

4.3 Failing to address root causes

The majority of interviewees indicated frustration that mitigation is "not really succeeding at the moment," but also worried about "giving up too early" and "abandoning everything else" in favor of climate engineering. There was a concern that climate engineering would be tantamount to "admitting that we've failed in mitigation." These worries were related to a widespread concern that climate engineering was "problematic" because it failed to address the "root causes" of climate change. Interviewees described climate engineering as "treating the symptoms but not the disease," "not actually tackling the source problem," putting "plaster over a wound," and "circumventing the problem."

Interviewees did not want climate engineering to be used as an excuse to avoid mitigation. They were especially worried that climate engineering might be "seen as the sole solution" or "a shortcut to avoid mitigation" and result in putting "systemic changes off for a longer period of time." Interviewees argued that there is a "risk" of envisioning climate engineering as a "silver bullet" and then failing to "care about anything else." They described the potential problem of using climate engineering as an "excuse" to avoid mitigation and adaptation, arguing that we would "still have a big problem in the end" and thus "it's very dangerous to focus on climate engineering only." Some interviewees worried that even research would come at the "expense" of other efforts to combat climate change.

Because of a widespread interest in mitigation, interviewees saw climate engineering as a "short-term" approach to addressing climate change. As this interviewee from Kenya explained, "I think it could be a temporary solution while the question of greenhouse gas emissions is brought under control. It can't be long-term. You can't just keep emitting and

doing climate engineering at the same time." Some interviewees described how "not addressing the underlying problem, the emissions problem" would lead to "doing more and more engineering in order to compensate" and insisted that would not be "a sustainable long-term solution."

4.4 Scale and unintended consequences

The overwhelming majority of interviewees also expressed deep concerns about unintended impacts of climate engineering. Interviewees described themselves as "cautious," "wary," and "skeptical" and wondered about the "consequences," "adverse effects," "side effects," and "unknowns" of climate engineering. They expressed concerns that climate engineering could "end up making the situation worse." Many concerns revolved around the unknown consequences of climate engineering and our ability to control the outcomes. One interviewee wondered if climate engineering would "create another false sense of security, that we're able to control these systems."

Many interviewees described feelings of unease about the idea of humans intentionally manipulating the climate. For example, one interviewee from the Solomon Islands stated, "to be honest, anything that involves manipulation of nature makes me nervous. I tend to think that there's going to be side effects and it's going to go terribly sideways." Some argued that "every time humans start messing with systems, they mess it up." An interviewee from Alaska said that, "if we try to jump into it too hard and too fast, we could set ourselves up for catastrophic failure. A lot of the things that we do won't be reversible."

The "massive" spatial scale of climate engineering and the potentially long-term character of such efforts influenced thinking about unintended consequences. As this interviewee from Kenya described:

> The beauty of the small-scale strategies is that if they backfire, they backfire by small area, and therefore the impact will not be as bad as a global initiative that backfires, because we have no other planet to go to. So if the global environment changes, we will all kick the bucket. But if a small village kicks the bucket, it's not as bad a risk as the global scale, where everybody is at risk.

Another interviewee from Kenya echoed this sentiment, saying:

> Could we create a bigger problem by doing this? ... Because it will be of a global nature, which means it will be at a very grand scale, the impacts experienced will also be at a grand scale. Whatever else we'll have to do to survive those impacts will also have to be at a grand scale. So we might possibly create a bigger problem.

Faced with the uncertainty of a global scale climate manipulation, some interviewees turned to local solutions, arguing that adaptation was preferable to climate engineering because it had "tangible results" and responded to local needs. According to this Alaska Native,

> These processes have been brought about as a result of very small things happening on a very large scale, so the reverse of that can also be true, that you can mitigate them and reeffect them at a small scale, or small changes over a very large scale … people still make a difference on a small scale.

Thus, adaptation efforts were believed to be more responsive to local needs and easier to control as compared with the larger-scale, longer-term prospect of climate engineering.

4.5 Conditional acceptance and local needs

Many interviewees argued that any support for future research on or development of climate engineering technologies was highly contingent and conditional. An important condition for many interviewees was more inclusive research. One interviewee from Kenya, for instance, said, "I think there should be continuing research involving as many people as possible, even from developing countries, in order to enable them to understand how we may be impacted and how we could contribute to it." Interviewees wanted to know that they would not only be made aware of potential impacts, but that the weather patterns and plant and animal species they depended on would be explicitly considered in research. As such, many interviewees wanted assurances that local impacts and local needs would be taken into consideration. In the words of one Alaska Native interviewee:

> With what we've experienced already in terms of our past history and outside influences dictating more than local people are dictating, it gets to be being a bit more protective in the sense of, is this the right thing? How much risk are we going to be subjecting ourselves to? ... Like I said early on, I'm a hunter. How is this going to impact the resources that I depend on for subsistence? I would like to see that there's no impact.

Many interviewees also expressed hopes that climate engineering technologies could be developed in such a way as to address the climate change impacts they were most concerned about. For example, as this Solomon Islander stated, "I'm optimistic that you can easily use those skills and technology and address the issues that are being experienced here, and one of them is water out in the atolls." However, interviewees also recognized that local climate adaptation is not the spatial scale at which current climate engineering proposals would work.

Rather than meeting the needs of vulnerable peoples, interviewees feared that climate engineering would be used in a way that would exacerbate existing global inequalities and/or make vulnerable populations even more dependent upon the decisions and actions of more powerful actors in distant places. One interviewee from Alaska emphatically expressed this fear:

> It's scary as hell to be dependent on some other person to dictate the weather or climate change. Like I mentioned, if it ever happens, whoever's rich enough is going to control it. That's the way I look at it. Whoever's got the dollars to do it, they're going to do it for their own benefit.

A Kenyan interviewee echoed this sentiment, saying:

> Where would the power be in terms of who decides what to do? In the past, countries with not as much wealth and the indigenous populations always get put on the back burner and don't get to decide these things. Would that be the same case?

Concerns about control were explicitly connected to the scale of climate engineering. As this Alaska Native put it, "It's too large-scale, to have that much control over something this big. It's too much responsibility. Who's going to be able to decide?" Questions about control were also connected to a worry that the expensive nature of the technology would make vulnerable populations even more dependent on wealthy countries.

Ultimately, interviewees wanted assurances of accountability for unintended consequences. As this Solomon Islander asked "who is going to be responsible if these things don't go right?" An interviewee from Kenya argued that climate engineering needs to consider "how best to

start to put safety nets into place so that then even if something backfires, it doesn't affect everybody … the people who are affected then can be taken care of." He concluded by clearly framing this as a condition for his acceptance, saying "then I think there is a future for climate engineering."

In short, the source of greatest anxieties among interviewees was related to the potential futures that climate engineering could bring about. They were particularly concerned about even greater dependence on wealthy, developed countries who could end up controlling the global climate. This anxiety was grounded in a sense that the goals and technologies involved in climate engineering were coming from outside of their communities, cultures, and perspectives. One interviewee from the Solomon Islands said simply, "It's not a local idea, it's a foreign idea." As such, interviewees expressed fears that large-scale interventions would not consider local resources and livelihoods, the loss of which would affect not only individuals, but entire social, cultural, and economic systems. To address this concern, interviewees wanted to see vulnerable populations not only being represented in discussions about climate engineering research and policy, but empowered to actually influence decisions that would affect them. In the words of one Alaska Native interviewee: "If [research] were to go forward, it would have to have a lot of very strong Native people involved and have them in a position where they could be a decision-maker … not just a yes-man or a yes-woman." Many interviewees viewed this type of meaningful participation and power in decision-making as one of the only ways to ensure climate engineering would actually benefit vulnerable populations.

5 Discussion

The results of this study extend the limited research on vulnerable populations' perspectives on climate engineering in several ways. Sugiyama et al. (2016) postulated that higher levels of concern about climate change in developing countries could be driving greater levels of support for climate engineering. Interviewees in this study explicitly linked their willingness to consider climate engineering to their high levels of concern about climate change and frustration with the current lack of mitigation. Rather than blanket "support" though, interviewees in this study expressed nuanced and even paradoxical views on climate engineering that might be more appropriately characterized as deeply reluctant and highly conditional acceptance.

Previous research on controversial technologies (including climate engineering) has noted similar perspectives. For example, Bickerstaff et al. (2008) used the term "reluctant acceptance" to describe responses to the reframing of nuclear energy as essential to low-carbon energy futures in the UK. Reluctant acceptance in that context was expressed by members of the British public as frustrated resignation that nuclear energy, though highly undesirable, may be indispensable for addressing climate change (Bickerstaff et al. 2008; Corner et al. 2011). More recently, some of the same researchers have noted similar perceptions of climate engineering. Pidgeon et al. (2013) found that members of the British public indicated reluctant acceptance of a proposed field trial of a prospective climate engineering technology. They concluded that scientists and policymakers should not mistake tentative support for a small-scale field trial as unconditional acceptance of future field trials, much less climate engineering more broadly. In the study presented above, desperation for solutions to climate change led interviewees to express reluctant acceptance of the need to consider climate engineering. Clearly exasperation

with lacking mitigation and adaptation efforts should not be misconstrued as unqualified support for climate engineering technologies.

In addition, interviewees in this study also expressed what previous research has described as 'conditional acceptance.' Macnaghten and Szerszynski (2013) have employed the term conditional acceptance to suggest that public support or approval of a novel technology may be highly contingent upon certain 'conditions of acceptability.' These conditions are often embedded in a recognition of social, political, and economic realities and the problematic futures that particular technologies might facilitate. Interviewees in this study relayed a number of concerns about the future that climate engineering could bring about. They feared potential impacts on local subsistence practices. They also worried about shifts in social, economic, and political power structures at the international level, including the potential for vulnerable populations to become even more dependent upon powerful actors in wealthy, developed nations. These concerns mirror Suarez and van Aalst's (2017) warning against 'predatory climate engineering' in which powerful global actors could intentionally or unknowingly create new threats and harms for the most vulnerable. To help guard against this, interviewees in this study went on to indicate conditions they would like to see met, including meaningful representation of diverse perspectives in future research and decision-making.

These conditions of acceptability resonate with findings from other studies documenting the perspectives of vulnerable populations. Participants in the Winickoff et al. (2015) study suggested that vulnerable populations may harbor concerns about countries in the Global North using climate engineering to deflect moral responsibility for climate change. Interviewees in the study presented here also expressed concerns that climate engineering would be used as a quick fix that would not address the underlying causes of climate change. In both cases, an important condition for acceptability would be major emitters demonstrating that climate engineering would not be used as a replacement for mitigation and adaptation by strengthening commitments to existing efforts.

Finally, similar to previous research involving vulnerable populations, another key condition for acceptance described by our interviewees was involvement of diverse perspectives in future research and governance efforts (AAS and SRMGI 2013; Beyerl and Maas 2014). The results presented above reaffirm the importance of inclusion and also help situate the need for inclusion within a broader historical context. Interviewees in this study situated their concerns about climate engineering within previous experiences of Western science and technology as vehicles of exploitation. As such, histories of dependence, fear of political marginalization, and recognition of the dramatic consequences of being left out of research and development were important factors shaping the views of vulnerable populations.

6 Conclusion

These findings suggest several important directions for future research. First, this study contributes to a growing body of literature that complicates the idea of vulnerable populations benefitting from climate engineering (see also Carr and Preston 2017; Flegal and Gupta 2017; Stilgoe 2015; Suarez and van Aalst 2017; Whyte 2012). As interviewees in this study suggested, whether and how vulnerable populations would benefit from climate engineering remain open questions. Future research needs to be attentive to not only how climate engineering could influence the biophysical impacts of climate change, but also to the ways that climate engineering could reshape social, political, and economic relationships at multiple scales.

This study also indicates that the concepts of reluctant and conditional acceptance might prove useful in understanding nuanced and even paradoxical perspectives on climate engineering in a variety of contexts. These concepts have been employed by researchers to explore a range of views on climate engineering in the UK (Pidgeon et al. 2013; Macnaghten and Szerszynski 2013). In this study, these concepts helped explain how conditions of vulnerability color perceptions of climate engineering across three diverse research sites. More specifically, interviewee expressions of reluctant and conditional acceptance highlighted the ways in which perceptions of climate engineering are situated within shared experiences of marginalization and exploitation in relation to climate change and its antecedents—colonialism, globalization, and neoliberalism. These concepts could provide a useful framework for comparing and contrasting hopes and fears related to climate engineering across developed and developing countries in future studies.

Recognizing reluctant and conditional acceptance could also help guard against potentially problematic assumptions in early survey work suggesting that distinct climate engineering "supporters" and "detractors" already exist. For example, the findings presented above suggest that the "support" for climate engineering that Sugiyama et al. (2016) detected in developing countries may be more indicative of extremely high concern about climate change, and an accompanying willingness to consider a range of alternative solutions—including climate engineering (see Macnaghten and Szerszynski 2013 for a similar critique of early survey work in developed countries).

Finally, this study reiterates calls for more meaningful inclusion of diverse perspectives in future climate engineering research (Cairns 2015; Preston 2012; Suarez et al. 2013; Washington Geoengineering Consortium 2013; Whyte 2012). It also helps explain why inclusion is critical from the perspective of vulnerable populations. First, interviewees understood climate impacts as local, tangible burdens on their communities, but envisioned responsibility for emissions and mitigation decisions at a global scale. Climate engineering was similarly viewed as having long-term, wide-ranging impacts, which would make unintended consequences in specific localities unavoidable. Similarly, the specter of global-scale governance of these potential planet-changing technologies elicited familiar feelings of being dependent on powerful people in faraway places. As such, interviewees asserted that meaningful engagement is not just about having a say in the future of climate engineering, but having a say in the ecological, social, and political relationships that climate engineering is embedded within. If climate engineering is to be seriously considered for its potential to help the world's most vulnerable populations, then those same populations should help decide what type of world climate engineering could bring about.

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