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The End of Experimentation

Geoengineering and Planetary Boundaries

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In May 2021, after a planned experiment in solar radiation management in Sweden was cancelled, the journal *Nature* published an editorial with a plea to 'give research into geoengineering a chance' (Editorial Board 2021). Solar radiation management involves several potential technologies that are designed to reduce the amount of the sun's energy reaching Earth's surface. These include, among other options, injecting aerosols into the stratosphere and brightening clouds over the ocean, both of which are meant to reflect a portion of solar radiation back out to space. The editorial reasoning was straightforward: (1) the best option for addressing climate change is mitigation, but the failure to arrest greenhouse gas emissions makes it increasingly unlikely that sufficient steps will be taken prior to the Earth system crossing critical climate thresholds. So, other options must be considered; (2) geoengineering has risks, including the moral hazard of misplaced confidence in technology, but without conducting experimental tests there is no evidentiary basis upon which to assess these risks against those of unabated climate change. The one-two punch of this line of reasoning supported an increasingly familiar position that does not advocate for geoengineering per se, but instead makes the case for geoengineering research. A few months later, in October 2021, an op-ed in the *New York Times* by David Keith (2021) made the same case from the opposite direction, arguing that geoengineering is the 'least bad' way to cool the planet. The shared premise of these arguments is that it is prudent to pursue experimental research into geoengineering. Indeed, it may even be the ethical thing to do.

Set in the context of the planetary boundaries, solar radiation management complicates concerns about aerosols. In the planetary boundaries framework, concerns over aerosols like dust, sulphates, and other particulates pivot on how they reduce the amount of sunlight reaching Earth's surface and in so doing affect planetary functions. Reducing radiation affects monsoon rains across Asia and affects biosphere integrity. It can affect regional climates and hemispheric patterns

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of precipitation, while too many aerosols can also have systematic effects on air quality for 'land and marine ecosystems' (Richardson et al. 2023: 8). But in the case of solar radiation management, where injecting aerosols is done intentionally, the concern is not over limiting aerosols but instead reckoning with whether some amount of additional aerosol loading may be needed for a last-ditch effort to stop runaway planetary heating. Here, then, is a case where it is not only a matter of two different planetary boundaries affecting one another, as so many of them do. Rather, at least one boundary is potentially being sacrificed for another: aerosols for climate. Other boundaries will be affected, too; aerosol loading affects the ozone layer, has knock-on effects on the biosphere and water cycle, and could forge unpredictable alliances with novel entities.

Responses to solar radiation management proposals are often anchored in ethical concerns. The ethics of sacrificing some degree of biosphere integrity, regional climate shifts, and hemispheric precipitation patterns all make it a significant moral wager. This is the case regardless of whether one appraises those risks in terms of utilitarian welfare functions or in terms of meeting (or foregoing) different obligations or duties. Additionally, many argue there are moral hazards to deploying solar geoengineering technologies (see Preston 2011, 2013; Tuana et al. 2012). For instance: solar geoengineering could kick-start an uncertain and complex chain of relationships and consequences that create unanticipated empirical and ethical challenges. Further, without a plan for how to stop using the technology there could be a kind of 'lock-in' where the climate would be hit with a warming shock should geoengineering be suspended. Worse, still, for many critics, is that geoengineering could become a license for further pollution since it avoids confronting the main driver of climate change: excessive greenhouse gas emissions. These types of concerns underpinned a response to the 2021 *Nature* editorial, in which Biermann (2021: 30) represented 17 signatories who argued that geoengineering was an unwelcome distraction from decarbonization efforts and that 'the current world order is unfit to devise and implement' the types of agreements required to manage the planet. The riposte from these critics drew on arguments that connect geoengineering to issues of governance, transparency, and democracy across different scales and actors, from states to Indigenous peoples (see also Gannon & Hulme 2018; Whyte 2018; Reynolds 2019). The critical response was followed a short time later with a call for a global 'non-use' agreement on geoengineering, which argues these technologies present intractable governance challenges that prevent their use in a just, globally inclusive manner (Biermann et al. 2022).

Despite the power of these responses, there is an ethical issue that they miss. And if we return to the context of the 2021 *Nature* editorial, this additional issue comes into view. That context includes, especially, a major report from the US National Academies of Sciences, Engineering, and Medicine (2021), which went

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to special lengths to make an ethical and empirical case for further research into geoengineering, particularly solar radiation management (SRM). The report represents one of the clearest expressions of a central normative assertion in support of geoengineering research: that experimentation is the best route through which to reach ethically justified decisions regarding solar radiation management. When reading the report, it is hard not to notice the pairing of ethics and experimentation. References to ethics occur on 77 pages and experimentation on 104; issues of justice and equity are not far behind, on 36 and 30 pages respectively. But it is not just the co-occurrence of these concerns that warrants attention. Rather, what is significant is that experimentation is deployed as the vehicle through which to reach decisions on ethical issues. As the National Academies of Sciences, Engineering, and Medicine (2021: 18) report states in the context of achieving an effective solar geoengineering (SG) research programme, a programme of experimentation should examine 'not only the atmospheric effects of SG but also the ecosystem, and economic, political, and ethical implications'.

The notion that experimentation is an appropriate venue for assessing empirical and ethical elements of geoengineering is the fundamental concern of this chapter. Major reports, editorials in major science journals, and op-eds in influential newspapers all suggest experimentation is a reasonable path forward – not ideal, perhaps, but prudent under the circumstances. For the rest of the chapter, I am going to argue that experimentation cannot be the venue for determining both the empirical and ethical considerations in geoengineering research. This is because experimentation is itself ethical, not neutral ground for adjudicating moral concerns. The upshot of my argument is that there may be a sound ethical basis for geoengineering research, but the view that experimentation provides that basis cannot simply be asserted. Nor is it sufficient to pepper reports with ethical concerns yet fail to appreciate how experimentation is not a value-free vehicle for addressing them. Rather, an argument is needed; one that addresses at least the two concerns that this chapter examines. The main argument, and where the bulk of the chapter focuses, explains the case for why appeals to experimentation are ethically inadequate. The second and much shorter argument is practical. It responds to arguments that claim those who quickly declared against geoengineering research – such as in the global non-use agreement – haven't yet considered what people in the Global South may have to contribute to debates and decisions regarding solar radiation management. I conclude by returning to considerations of aerosols and planetary boundaries.

25.1 Experimentation as Ethical Disposition

The idea that experimentation is an appropriate arena in which to convene empirical and ethical discussions regarding solar radiation management is not new.

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David Keith (2013) deployed this argument in his 'case for geoengineering' as he laid further groundwork for pursuing research on planet shaping technologies (see also Morton 2016). Yet the idea of experimentation has witnessed a resurgence in view of increases to greenhouse gas emissions that continue to climb higher. In 2023, UNESCO's World Commission on Scientific Knowledge and Technology published its assessment of ethics and geoengineering. That report, like the US National Academies assessment, emphasizes that any experiments with SRM should be at small scales (ideally indoors) and constrained by a series of ethical considerations regarding transparency and conflicts of interest, and that they should also account for different cultural and disciplinary concerns (UNESCO 2023). That same year, the United Nations Environment Programme (UNEP) came to a similar conclusion: there was not enough known about SRM technologies to appraise their risks on matters ranging from impacts on the ozone layer to implications for Indigenous peoples; so, its first recommendation was that a more robust scientific review process by a global body of experts in natural and social sciences be put in place (UNEP 2023: 25). The history of solar radiation management and its current momentum, then, both point towards experimentation as needed to answer empirical questions and to thereby provide the evidence through which to settle ethical concerns.

What is the objection to experimentation? It seems like a good antidote to what is currently happening. For instance, in 2022 the start-up company *Make Sunset* lofted balloons filled with sulphur dioxide high into the atmosphere and boasted they could release more aerosols if people wanted to buy the 'cooling credits' they claimed this achieved. Shortly after, another article in *Nature* pounced on the idea, arguing that the scary fact that anybody can pump aerosols skyward is all the more reason to research geoengineering (see Ricke 2023). This wasn't the first time this kind of thing happened. In 2012 the Haida people hired a fly-by-night scientist to dump 120 tons of iron oxides and iron sulphates off the coast of Haida Gwaii (in the Pacific Ocean off Canada's west coast). This geoengineering project by an Indigenous nation was meant to stimulate the ocean life that ultimately draws carbon down to the ocean floor (Gannon & Hulme 2018). There is, of course, an important difference between start-up publicity stunts, ill-defined research, and careful experimentation. Shouldn't we favour systematic programmes rather than just accept ad hoc interventions? Before digging in on this question, it is important to also note that geoengineering research does not always entail real-world experimentation. For instance, atmospheric modelling doesn't necessarily entail actual release of aerosols. Here, however, I focus on experimental arguments involving actual releases because these are among the most salient sources of knowledge once the theories and models recommend a particular technological path for intervening in Earth's solar radiation budget.

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A key aspect of my argument against experimentation as a vehicle for ethical decision-making was put succinctly by the late philosopher Bernard Williams. In his work *Philosophy and the Limits of Ethics*, Williams (1985: 172) argued that a society given over to 'experiments in living' does not necessarily increase 'the chances of living in the best way. It is one sort of society rather than another, and there are various forms of living that it rules out; indeed, those ruled out could include those most worth living'. When Williams made this argument he had a specific target in mind – liberal forms of experimental rule proffered by the utilitarian John Stuart Mill. My argument is not beholden to a critique of either liberalism or utilitarianism, but it equally points out the fact that experimentation orients ethical questions about geoengineering in one way and not in others. In other words, experimentation operates as a kind of ethical disposition – a particular way of arranging concerns and the relations among them. In so doing, experimentation rules out alternate, non-experimental modes of ethics by fiat. This ring-fencing is an important part of what makes experimentation inappropriate as a venue for convening ethical decisions.

One objection that a proponent of experimental research into geoengineering might make is to point out the difference between what Williams termed experimental 'ways of living' versus the more constrained aims of a scientific experiment. This sort of objection emphasizes that experimentation in one area is different than saying *everything is experimental*. If that is true, the proponent could then argue, we can hive off the experimental aspect of geoengineering in a way that does not commit us to making ethics experimental too. There are two challenges this objection faces. The first is that scientific experiments are not conducted in social vacuums. Historians and philosophers of science have routinely made this point plainly and powerfully enough over recent decades that the scientific knowledge once declared to be value-free is now increasingly recognized for the many judgments through which theories, technologies, norms, and institutions make science reliable (Daston & Galison 2010; Oreskes 2019; Cartwright et al. 2022). Risks, too, are assessed not with respect to the universe of total possibility but through culturally situated practices and bounded rationalities that make satisfying multiple constituencies not only a matter of presenting experimental results (cf. Rayner & Cantor 1987). As result of this tangle, the idea that experimentation retains some kind of special status amidst value-loaded sciences is not tenable. This is part of why, I would suggest, major reports by scientific and environmental agencies are trying to show that geoengineering research can be ethical in the first place – because it needs normative legitimacy even at the experimental phase.

The second problem with trying to parse geoengineering research from the argument that it commits decisions to one ethical disposition by fiat is that, if it

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does not, then proponents face a different challenge: exactly how will experimentation inform ethical decisions? Philosophically, there is an important logical difference between what Nancy Cartwright (2007) termed 'hunting causes and using them'. Suppose, for instance, that an experiment suggested with strong evidence that *x* would be the result of applying solar geoengineering at scale. This still would not provide us with the full range of morally relevant information about how the causal explanations of *x*, as determined by the experiment, ought to bear on different uses of the technology – for how long, at what scale, and with what weight assigned to other trade-offs. These kinds of ethical decisions are a species of what Marcus Düwell (2013: 9) terms 'mixed judgments' in which different disciplines and practices offer partial perspectives on a shared moral concern. These broader considerations are among the most salient questions that opponents of solar geoengineering raise. In other words, if proponents of solar radiation management seek to keep experimentation cloistered from its social context (as my first point earlier suggests is hard to do), then they are left no better off in terms of being able to settle ethical questions through answers to empirical questions. The cloistering has the opposite effect: it cuts off the presumptive connection of ethics and inquiry that the case for geoengineering research via experimentation rests on.

The ball is back in the court of those advancing experimentation as the vehicle for making decisions across the empirical and ethical considerations entailed by using aerosols to manage solar radiation. What can be noted in this, the first of my arguments, is that I have not closed the door to experimentation being ethically appropriate. Rather, I have pointed out that this requires a defensible argument that convincingly shows why this is so. To set up experimentation as the site of decision-making about the prospects for planetary geoengineering is to invoke an entire apparatus of inquiry that goes far beyond the boundaries of any single experiment or set of experiments. Additionally, and because experimentation is entangled with the values, theories, and technologies implicated in establishing scientific claims, the argument for experimentation will, in fact, need to confront the central insight provided by Bernard Williams: giving decisions over to experimentation rules out other ways that decisions might be reached. Experimentation entails a particular way of arranging ethical concerns – a disposition – in relation to scientific practices and this is not a morally neutral endeavour.

25.2 Experimentation in Planetary Perspective

In February 2023, it was widely reported that Earth's temperature averaged over 1.5°C above the pre-industrial average for the first calendar year ever. That year, then the hottest on record, saw significant rises in ocean surface temperatures in the

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north Atlantic and elsewhere. Explaining the rapid rise in temperatures, which are a decade ahead of what was predicted in many climate models, has often turned to aerosols. It has been understood that aerosols have long been having a cooling effect on Earth's temperature, even though the sensitivity of climate to them was not fully understood (see Andreae et al. 2005). One of the first efforts to quantify these effects was published in 2018 and estimated that aerosols were already cooling Earth by 0.5°C (possibly up to 1.1°C) and that reductions in aerosol loading would increase precipitation 2–4.6 per cent and make extreme weather even more likely (Samset et al. 2018). The sixth (and most recent, as of this writing) Intergovernmental Panel on Climate Change (2021) report considered the upper limit of aerosol cooling to be as high 0.8°C. The counterintuitive concern then arose – what are the ethics of reducing polluting aerosols when they are *already* a kind of de facto geoengineering? Would rapid reduction lead to the kind of climate shock that worries those who want a clear and agreed plan for how to phase down any future, purposeful form of solar geoengineering?

In this context, the case for experimental research into solar radiation management takes on a different tenor. There is already unintentional cooling of the earth through historical aerosol emissions. Could this be levered into a need to understand how to avoid rapid temperature increases that could arise from effective reductions in aerosol emissions? If so, that might be a further basis for legitimating geoengineering research. This is because temperature rises that are much faster than anticipated pose the potential for a climate shock for which species, cities, economies, and social stability might not have adequate adaptive equipment or capacity. In this case there is a kind of practical urgency. Reducing emissions is critical to reducing planetary heating, but it is also critical to avoid moral harms caused by rapid climate heating from aerosol emissions reductions. This is especially the case for those most vulnerable to climate change, such as those in the majority world (for example: the Global South). This argument is not simply about 'giving geoengineering research a chance' as the editorial in *Nature* put it. Rather, it is about supporting the best way to learn about interactions of aerosols and climate.

In this context, Táíwò and Talati (2022) recently argued that one of the problems with current debates about geoengineering research is that many critics base their arguments on standards their own arguments don't meet. This is especially the case, they argue, when the argument is made that harms may accrue disproportionately to people and environments in the Global South through decisions made by actors in the Global North. Such arguments, Táíwò and Talati (2022) reason, often succumb to the inconsistency of never having asked people in the Global South their perspective. So, in this way, the argument that geoengineering cannot be done owing to lack of transparent or democratic global

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governance fails to meet its own standard of confronting undemocratic or non-transparent forms because it simply asserts its decision without consulting those in the Global South. They think it too presumptive to declare no geoengineering research should take place without consulting those most vulnerable to the risks and trade-offs between climate heating versus managing radiation.

My argument is not of the sort Táíwò and Talati (2022) target. I have not claimed no research could ever be justified, only that the argument for experimentation cannot also double for ethical warrant. My argument also holds for practical questions around urgency. Responses to urgent moral questions are not appropriately confined to experimental dispositions either. They require a suite of tactics. If experimentation is to be principal or even prominent among them, it will require an argument for why this is so, not a default response to crisis. Through deliberations of the kind that Táíwò and Talati (2022) don't wish to prematurely exclude, a more transparent and democratic appraisal could include experimentation as part of a governance package. Here, however, experimentation is already situated differently. Experimentation would be one among many aspects of ethical decision-making – transparency, democracy, and the values these rely on – regarding solar radiation management, not its primary disposition.

25.3 Conclusion

The argument for research into solar radiation management needs a justification that does not collapse ethical decision-making to an experimental disposition. This is an issue that is also likely to become increasingly important for the planetary boundaries framework. That framework, at present, recognizes existing aerosol loading is already reducing monsoon rains and that there are large uncertainties and asymmetric effects across hemispheres in the interactions among different types and sources of aerosols, clouds, and atmospheric climate forcing (Richardson et al. 2023; cf. Intergovernmental Panel on Climate Change 2021). It also places aerosol loading among the remaining boundaries that have not yet been crossed – implying, potentially, that adding aerosols could be permissible from the perspective on Earth system stability and resilience that the framework commits itself to. The most recent assessment, however, also states that 'a much better systemic and quantitative understanding of the hydroclimatic, ecological, and biogeochemical effects of asymmetric aerosol forcing is needed to refine the aerosol loading boundary' (Richardson et al. 2023: 8). How will this more systematic, quantitative understanding be achieved? If it is to be through experiments that involve purposeful aerosol loading, a much more robust argument will be needed than just giving over ethical decisions to experimentation.

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