Geoengineering in a climate of uncertainty[*]

If I had only known, I would have been a locksmith[1]

Against the background of continuing inadequacy in global efforts to address climate change and apparent social and political inertia, ever greater interest is being generated in the idea that geoengineering may offer some solution to this problem. The definition of this concept is itself a matter of dispute but roughly speaking, geoengineering can be understood as the intentional, large-scale modification of the Earth system. Following the IPCC's 2011 Expert Meeting on Geoengineering, this subject was discussed by all three working groups of the IPCC for the first time in its latest report.[2] Given that geoengineering is an ethically and politically contentious topic, some might worry that this is a sign of its entering the mainstream.

A diverse range of techniques are often placed under the heading of geoengineering. In this chapter, I start by offering a particular definition of the concept and looking at how such techniques are situated in terms of the different responses that are available for addressing

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[1] Albert Einstein (quoted in W. Wells, 'Our technical dilemma *or* an appraisal of man as a species bent on self-destruction', *Bulletin of the Atomic Scientists*, 16 (1960), 364).

[2] This is a new topic in particular for Working Group I: charged with reviewing research on the physical science of climate change. See 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, and M. Mastrandrea (eds.), *Meeting report of the Intergovernmental Panel on Climate Change expert meeting on geoengineering* (Potsdam, Germany: IPCC Working Group III Technical Support Unit, Potsdam Institute for Climate Impact Research, 2012).

climate change. I then briefly discuss some of the major ethical arguments for and against activities within this sphere; activities including lab-based research, field testing and deployment. Though many of the ethical and political issues raised by geoengineering remain unsettled – and international institutions for the governance of geoengineering activities are yet to be established – attempts are frequently made to justify further scientific research into the possible impacts of deployment. Lab-based research in particular – investigating geoengineering through the use of models, computer simulations and contained experiments – is perceived by many scientists to be ethically unproblematic. In fact, some advocate a 'research first' approach, which would see extensive lab-based studies conducted *before* international institutions for the governance of geoengineering activities are established.[3] One might think that by improving our understanding of these techniques and the issues that they raise, such research will enable us to determine the appropriate form of geoengineering governance.

I am not going to take a position, here, on whether or not geoengineering could ever be morally justifiable. My goal in this paper is more modest – but also has broader implications. I aim to show that *even if* some form of geoengineering might be ethically acceptable in certain specific circumstances, lab-based research into such techniques could nevertheless have morally problematic consequences. I support this claim by explaining that our current state of uncertainty regarding how the impacts of geoengineering interventions could be geographically distributed may help to promote international agreement on fair rules for the governance of geoengineering. In these circumstances of scientific uncertainty, international actors also face uncertainty regarding who the winners and losers could be with respect to potential rules of geoengineering governance, thereby obstructing the pursuit of self-interest in the selection of such rules. Instead of a research first approach, then, we have reason to take a *governance first* approach – ensuring that fair international institutions to regulate geoengineering activities are established *before* further research is conducted into how the costs and benefits of such interventions could be distributed.

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[3] On the 'research first' proposal, see S. M. Gardiner, *A perfect moral storm: the ethical tragedy of climate change* (Oxford: Oxford University Press, 2011), 349ff.

Climate change and geoengineering

In order to understand why geoengineering is sometimes proposed as a solution to climate change, it is important to know how climate change takes place. Climate change results from the enhanced greenhouse effect, created by increased atmospheric concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO_2) and methane (CH_4). Of the solar radiation reaching the Earth system, roughly 30% is reflected back into space and about 20% is absorbed by the atmosphere. The rest is absorbed by the Earth's surface and emitted outwards again in the form of longwave radiation, and the greenhouse effect takes place when GHGs and clouds act like a blanket to prevent some of this longwave radiation from escaping, trapping heat in the lower atmosphere.[4] GHGs are added to the atmosphere via a number of natural processes (such as respiration and decay). They are removed from the atmosphere by mechanisms termed *sinks* and may be stored (sequestered) in reservoirs. For example CO_2, the most significant anthropogenic GHG, is sequestered by the ocean, vegetation and soils.[5]

Due to human activities, GHGs are now being added to the atmosphere much faster than they are removed by natural processes. Two major contributing factors to this accumulation are the burning of fossil fuels (which releases GHGs into the atmosphere) and deforestation (which reduces the amount of atmospheric CO_2 that is sequestered in vegetation – vegetation sometimes referred to as *biomass*). By reducing the amount of longwave radiation escaping into space, the enhanced greenhouse effect alters the Earth's energy budget, with significant consequences for the climate system. That the climate system has warmed is "unequivocal", with many of the changes observed since the 1950s "unprecedented over decades to millennia".[6] This warming can be expected to have various knock-on effects for the climate, including: sea level rise, changes in atmospheric and oceanic circulation patterns, increased incidence and intensity of precipitation, droughts,

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[4] See T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley (eds.), *Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK and New York, NY: Cambridge University Press, 2013), 126-7.

[5] *Ibid*., 544-5.

[6] *Ibid*., 4.

heatwaves and other extreme weather events. Increased atmospheric concentrations of CO_2 also lead to ocean acidification.[7]

The two major options for dealing with the problem of climate change are mitigation and adaptation. Mitigation is commonly taken to refer to "a human intervention to reduce the sources or enhance the sinks of greenhouse gases".[8] Such interventions include burning fewer fossil fuels; developing carbon capture and storage (CCS) capability; reducing the burning of biomass that accompanies deforestation; preserving existing forests and planting new ones. Adaptation, on the other hand, refers to an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities".[9] Examples of adaptations include coastal protection infrastructure, crop and livelihood diversification, insurance, water storage, disaster responses and migration.[10]

In three out of the four hypothetical scenarios for future atmospheric GHG concentrations considered by the IPCC in its latest report, global surface temperature by the end of the twenty-first century was found *more likely than not* to exceed 2°C (the internationally defined limit beyond which anthropogenic interference with the climate system is said to become "dangerous")[11], and in two of those scenarios it was judged *likely* to exceed this target.[12] Only in the stringent mitigation scenario was warming deemed *unlikely* to exceed

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[7] *Ibid.*, 79-113.

[8] *Ibid.*, 1458.

[9] M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (eds.), *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK and New York, NY: Cambridge University Press, 2007), 869.

[10] *Ibid.*, 721-2.

[11] See unfccc.int.

[12] Stocker *et al.*, *Climate change 2013*, 102. The IPCC has to base its projections of climate change on assumptions about future GHG concentrations and other climate forcings. In the most recent report these hypothetical future scenarios are termed "Representative Concentration Pathways" (RCPs), with the four RCPs considered designed to be indicative of "a range of 21st century climate policies" (*Ibid.*, 29). They are: RCP2.6 (a strong mitigation scenario where atmospheric concentrations of CO_2 reach 421 parts per million (ppm)); RCP4.5 and RCP6.0 (stabilisation scenarios where concentrations reach 538 and 670ppm, respectively); and RCP8.5 (a high emissions scenario where concentrations reach 936ppm). The following expressions, used by the IPCC to state its evaluation of the likelihoods of certain outcomes, should be read as follows: *likely* (66 to

2°C, and this scenario would require that we eventually achieve *negative* global emissions through the use of large-scale bio-energy with carbon capture and storage (BECCS) – a method that some would class as geoengineering.[13] These projections thus help to explain both why increasing interest is being generated in the idea of geoengineering, and why some have begun to worry about the normalisation of such techniques.[14]

Defining geoengineering

How to define geoengineering is a matter of dispute, but the term itself offers a guide to its meaning: the noun 'engineering' referring to "the branch of science and technology concerned with the development and modification of engines (in various senses), machines, structures, or other complicated systems and processes using specialized knowledge or skills"; and the prefix 'geo' indicating that such development and modification relates, in particular, to the complex system that is the Earth.[15] Geoengineering is often taken to refer only to modifications of the Earth system – or the climate system – that are *designed to address the problem of climate change*.[16] I instead allow geoengineering to be understood more broadly, taking it to refer to *any* intentional, large-scale (regional or global) modification of the Earth system. Geoengineering is almost always discussed as a means by which to counteract climate change, but such interventions could conceivably be designed some other reason – for example, as a method of warfare.

100%); *more likely than not* (>50-100%); and *unlikely* (0-33%). Italics are used to indicate that these terms should be understood in a technical sense (*Ibid*., 36).

[13] *Ibid*., 526.

[14] See, for example, ETC, 'IPCC and geoengineering: the bitter pill is also a poison pill', ETC News Release, 16 April 2014. www.etcgroup.org/content/ipcc-and-geoengineering-bitter-pill-also-poison-pill (accessed 20 May 2014). I do not intend to imply that a desire to prevent dangerous climate impacts is the only – or the predominant – reason why geoengineering proposals are receiving increasing levels of attention. Some parties will be attracted to geoengineering because it provides a diversion that might help to delay meaningful action on climate change, or distract from the fact that such action is not taking place; because it offers a way to make money through patented technologies; because they think it might prolong the ability to use or profit from fossil fuels; or simply because they find it an interesting idea.

[15] See the Oxford English Dictionary (www.oed.com).

[16] See, for example, J. Shepherd, K. Caldeira, P. Cox, J. Haigh, D. Keith, B. Launder, G. Mace, G. MacKerron, J. Pyle, S. Rayner, C. Redgwell, and A. Watson, *Geoengineering the climate: science, governance and uncertainty* (London: Royal Society, 2009), 77; Stocker *et al*., *Climate change 2013*, 1454.

In the context of climate change, geoengineering proposals are often divided into two sub-categories: Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR).[17] CDR techniques aim to reduce atmospheric concentrations of CO_2 by increasing the uptake of natural sinks and reservoirs (terrestrial and oceanic) or engineering new systems that will remove CO_2 from the atmosphere. Examples include: enhancing terrestrial sinks through afforestation and reforestation; enhancing marine sinks through ocean fertilisation (to encourage phytoplankton growth and carbon uptake); biomass sequestration (where the carbon drawn down by vegetation is stored, for example by burying or conversion into charcoal); BECCS (where biomass is instead used as a fuel and the resulting CO_2 is captured and stored); and industrial processes that capture CO_2 from the air.[18]

SRM, on the other hand, does not reduce atmospheric concentrations of GHGs. SRM techniques are instead designed to reflect more incoming solar radiation back outward into space, thereby preventing global or local temperatures from increasing as much as they would otherwise for any given increase in atmospheric concentration of GHGs. Proposals include preventing as much solar radiation from reaching the Earth by positioning sunshields in space; or increasing the Earth's albedo (that is, the fraction of solar radiation that it reflects) by painting roofs and other surfaces white, increasing crop reflectivity, covering deserts with reflective surfaces, whitening clouds and injecting particles into the stratosphere to scatter more sunlight back into space.[19]

It is important, however, to note that the set of geoengineering proposals for responding to climate change cannot simply be defined as the collection of all CDR and SRM methods. Firstly, CDR and SRM techniques are not always of sufficient magnitude to plausibly count as geoengineering – small-scale afforestation and surface-whitening being two examples. Secondly, not all potential geoengineering responses to climate change fall into one of these categories. Techniques may be sought to remove other GHGs (such as CH_4) from the atmosphere, suggesting that we might want to consider a broader category of *greenhouse*

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[17] See Shepherd *et al.*, *Geoengineering the climate*, 1.

[18] *Ibid.*, §2.2-3.

[19] *Ibid.*, §3.3.

gas removal (GGR).[20] Another idea that doesn't fall into either category is "cirrus thinning", which seeks reduce the greenhouse effect of high-altitude cirrus clouds;[21] and presumably other geoengineering responses may be imagined that do not constitute CDR or SRM either. And finally, it is not clear how best to distinguish between CDR, SRM and the more commonly considered options for dealing with climate change: those of mitigation and adaptation.

This difficulty in categorising and situating geoengineering methods has recently been addressed in two papers, one by Clare Heyward and one by Olivier Boucher *et al*. Heyward proposes that rather than considering geoengineering to be a third way to address climate change – alongside mitigation and adaptation – we may more usefully distinguish between five responses to this problem, and Boucher *et al*. offer an alternative five-way categorisation.[22] In what remains of this section, I draw on both accounts in order to provide a six-way typology of responses to climate change. I should note that Heyward presents her account not only in order to situate SRM and CDR with respect to other options for addressing climate change, but also to argue that the term 'geoengineering' should be abandoned because it is "too broad [and] too vague" to be of use.[23] I will not heed this advice, instead drawing on Heyward's typology to offer a means by which we can attempt to

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[20] The GGR terminology is suggested in O. Boucher, P. M. Forster, N. Gruber, M. Ha-Duong, M. G. Lawrence, T. M. Lenton, A. Maas, and N. E. Vaughan, 'Rethinking climate engineering categorization in the context of climate change mitigation and adaptation', *WIREs Climate Change*, 5 (2014), 31. In the Royal Society report where the partition of geoengineering techniques into SRM and CDR is suggested, it is acknowledged that methods to remove other GHGs might be sought (Shepherd *et al*., *Geoengineering the climate*, 61).

[21] Stocker *et al*., *Climate change 2013*, 627-8. Cirrus thinning is "not strictly a form of SRM", although it is often discussed alongside such techniques (*Ibid*.). This is because cirrus thinning would not reflect more of the sun's radiation back outward into space – as SRM is supposed to – but is instead designed to enable more outgoing, longwave radiation (emitted from the Earth's surface) to escape by reducing the greenhouse effect of cirrus clouds.

[22] C. Heyward, 'Situating and abandoning geoengineering: a typology of five responses to dangerous climate change', *Political Science & Politics*, 46 (2013), 25; Boucher *et al*., 'Rethinking climate engineering categorization', 29-30.

[23] Heyward, 'Situating and abandoning geoengineering', 26. See also Jamieson, who suggests that the term 'geoengineering' "does not delineate a distinct category of responses, but rather expresses the suspicion of a speaker towards responses that she sees as in some way novel, weird, exotic, unfamiliar, or untested" (D. Jamieson, 'Some whats, whys and worries of geoengineering', *Climatic Change*, 121 (2013), 536).

determine whether a proposed response to climate change should be deemed to constitute geoengineering.

Following Heyward – and differentiating between responses to climate change "by where they occur in the process between emitting GHGs and the loss of human wellbeing"[24] – six categories of response to climate change that might be distinguished are:

(A) The reduction of GHG emissions
(B) GGR
(C) SRM
(D) Non-GGR/SRM geoengineering techniques
(E) Adaptation
(F) Rectification

Though they go about it in different ways, methods from categories (A) and (B) have in common that their ultimate aim is to reduce atmospheric concentrations of GHGs. Techniques in (C) are supposed to reflect more of the sun's radiation back into space. (D) I introduce as a category for geoengineering responses to climate change that *do not* fall into categories (B) or (C) – for example, cirrus thinning.[25] (E) encompasses adjustments designed to increase human resilience to climate impacts (as I will shortly explain, (E) may have some overlap with (C)). And finally – when other options fail to prevent important human interests being negatively impacted – measures from category (F) may be necessary to address the resulting loss and damage.[26]

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[24] Heyward, 'Situating and abandoning geoengineering', 25.

[25] See fn. 21.

[26] These categories relate to those proposed by Heyward and Boucher *et al*. as follows. Heyward's five categories are: emissions reductions (A); CDR (B); SRM (C); adaptation (E); and rectification (F). Boucher *et al*. distinguish between "anthropogenic emissions reductions" (A); domestic GGR and transboundary GGR (which together constitute (B)); "regional to planetary targeted climate or environmental modification" (which encompasses (D) and the large-scale methods from (C)); and "climate change adaptation measures including local targeted climate or environmental modification" (which includes (E) and the small-scale methods from (C)).

As the IPCC notes, whether a given activity constitutes geoengineering will depend on its "magnitude, scale, and impact".[27] I have defined category (D) such that it only contains techniques with sufficient magnitude and impact to constitute geoengineering. To decide which techniques from within (B) and (C) count as geoengineering, however, one must attempt to determine which of these methods would constitute a large-scale (regional or global) modification of the Earth system.[28]

The distinction between large-scale and small-scale GGR is likely to be fuzzy and – when the effects of a method are hard to predict – it might not be clear in advance whether a given technique should be deemed to constitute geoengineering, mitigation, or both.[29] Some might also debate whether a given GGR technique (e.g. large-scale industrial CCS) constitutes a *modification* of the Earth system or rather an attempt to reduce human modification of the climate. A GGR technique that *is* generally agreed to constitute geoengineering is ocean fertilisation. One that is not is the small-scale enhancement of terrestrial sinks.

Most SRM measures, on the other hand, are designed to have global effects and thus count as geoengineering by this definition – though not all. As Boucher *et al*. point out, some small-scale SRM methods (such as the introduction of more reflective roof and road surfaces

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[27] Stocker *et al*., *Climate change 2013*, 1449.

[28] The difficulty in determining whether a given intervention would count as a *large-scale modification* of the Earth system helps to explain the controversy over which techniques should be regarded as geoengineering. Often the relevant scale is taken to be regional or global, but this doesn't resolve matters unless we know how large an area has to be before it counts as a *region*. Boucher *et al*. suggest an area around 300km x 300km (Boucher *et al*., 'Rethinking climate engineering categorization', 27), but any such stipulation will be ad hoc.

[29] Boucher *et al*. (*Ibid*., 32) draw a similar distinction between *domestic* GGR (which they suggest corresponds with the normal definition of mitigation) and *transboundary* GGR (commonly understood as geoengineering). As the IPCC notes, the distinction between GGR and mitigation "is not clear and there could be some overlap" (Stocker *et al*., *Climate change 2013*, 1449-50). One could choose to use 'mitigation' in a *narrow* sense, to refer only to (A) – that is, emission reductions (Heyward suggests such an understanding). At the other end of the spectrum, one could have a *liberal* understanding of mitigation that also includes all GGR techniques – so that (A) *and* (B) are both taken to constitute mitigation (see Jamieson, 'Some whats, whys and worries', 529). Or one might define mitigation by stipulating an alternative partition on (B). For example, one could appeal to the idea of the *naturalness* of the GGR method in question: taking mitigation to incorporate the enhancement of *natural* sinks, but not *newly engineered* mechanisms that remove GHGs from the atmosphere (on this distinction, see Boucher *et al*., 'Rethinking climate engineering categorization', 28).

and increased crop albedo) might more appropriately be considered adaptations. These measures have minimal transboundary effects, instead serving to cool the Earth's surface *locally*; with the potential benefit of preventing the "urban heat island effect" and maintaining crop productivity.[30]

As Christopher Preston suggests, it appears "prudent" – given the broad range of methods that could be taken to constitute geoengineering – to evaluate the ethical aspects of each technique on an individual basis.[31] This separate analysis should help us to avoid getting bogged down in definitional disputes that distract from the more important, normative questions surrounding such proposals. Even if a particular GGR or SRM technique does not appear to constitute geoengineering, analogous ethical issues may arise – or alternative problems concerning the ability to access, control and profit from these inventions. Thus, as Heyward argues, it is important to focus on "the specific features of proposed technologies" in order to assess their ethical and practical merit.[32]

A number of geoengineering proposals are, however, united in their possession of three features that give rise to the particular normative issue on which I will focus. These techniques – including large-scale SRM, ocean fertilisation and cirrus thinning – have potentially *global effects*, which are expected to be *unevenly distributed* geographically, but are *currently uncertain*. In virtue of the first two characteristics, such proposals raise a challenging problem of global justice: one that should be addressed through the creation of just and effective governing institutions. However, there is reason to think that international agreement on fair rules for the governance of geoengineering activities is more likely to be obtained in our current conditions of uncertainty regarding the global distribution of geoengineering impacts. When geoengineering proposals possess these three features, we therefore have reason to establish sound institutions of governance *before* attempting to reduce such uncertainty through further scientific investigation.

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[30] Boucher *et al.*, 'Rethinking climate engineering categorization', 26.

[31] C. J. Preston, 'Ethics and geoengineering: reviewing the moral issues raised by solar radiation management and carbon dioxide removal', *WIREs Climate Change*, 4 (2013), 23.

[32] Heyward, 'Situating and abandoning geoengineering', 26.

I should note, before continuing, that it is unclear how successful scientific investigation can actually prove in providing information about the probable impacts of geoengineering interventions. Some reject further research into geoengineering because they believe it is *impossible* to acquire such knowledge: Gerd Winter, for example, suggests that we might be in a state of "unavoidable ignorance" regarding the safety of SRM techniques, and thus that further research into such proposals is pointless at best.[33] However, even if our ignorance regarding the distribution of geoengineering impacts is inescapable, the argument that follows remains applicable insofar as scientific studies have the potential to reduce the *subjective* uncertainty of parties in a position to implement geoengineering techniques – by leading them to believe that certain interventions will be in their self-interest.

Ethical and political issues concerning geoengineering

As stated above, in the rest of this piece I will be focussing only on issues raised by geoengineering techniques with potentially *global effects*, which are expected to be *unevenly distributed* geographically, but are *currently uncertain*. An obvious worry about such techniques is that they could have severe side effects for ecosystems and human societies. Their actual impacts are hard to predict, however, because there is no test system on which large-scale modifications of the Earth system can be trialled.[34] Projections must instead be made with the help of computer simulations, utilising models that currently appear far from adequate for this purpose – especially when tasked with predicting impacts at the local or regional level.[35] Thus, as Steve Rayner notes, disputants on every side of the

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[33] G. Winter, 'Climate engineering and international law: last resort or the end of humanity?' *Review of European Community & International Environmental Law*, 20 (2011), 289.

[34] See A. Robock, M. Bunzl, B. Kravitz, and G. L. Stenchikov, 'A test for geoengineering?' *Science*, 327 (2010), 530-1.

[35] P. J. Irvine, A. Ridgwell, and D. J. Lunt, 'Assessing the regional disparities in geoengineering impacts', *Geophysical Research Letters*, 37 (2010), 1; Shepherd *et al*., *Geoengineering the climate*, ix, 54. Past volcanic eruptions offer some evidence regarding the expected effects of stratospheric particle injection. However, as an analogue they are far from ideal because their effects "might only last for a few years", whilst stratospheric particle injection would have to take place "for decades or centuries" (Shepherd *et al*., *Geoengineering the climate*, 29). A "proper assessment" of the effectiveness of ocean fertilisation poses similar challenges, requiring "consideration of the entire ocean carbon system, and the use of ocean carbon models" (*Ibid*., 17).

debate surrounding geoengineering for now appear to be united in acknowledging "that we currently know very little".[36]

SRM, in particular, "would itself inevitably lead to climate change",[37] because it would have "regionally different climate impacts".[38] The effects of SRM on local temperatures will be varied and such methods have the potential to disrupt the hydrological cycle (leading to changes in precipitation) and to disturb atmospheric and oceanic circulation patterns. Furthermore, SRM could lead regional climatic conditions to migrate away from their historical baseline states in disparate ways as time progresses, "meaning that "'optimal' SRM activities imply different things for different regions".[39] Some of these changes in regional climates "might lead to impacts that are more serious than the amount of climate change that is being offset".[40] In the case of cloud whitening, for example, "while some areas benefit from geoengineering, there are significant areas where the response could be very detrimental".[41] There is also reason to think that stratospheric particle injection might "disrupt the Asian and African summer monsoons", resulting in drought conditions that would place "the food supply for billions of people" at risk.[42] Similar effects on the Indian and African monsoons could arise from desert surface albedo modification.[43]

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[36] S. Rayner, 'To know or not to know? A note on ignorance as a rhetorical resource in geoengineering debates', *Climate Geoengineering Governance Working Paper Series*, 010 (2014), 16.

[37] D. J. Lunt, A. Ridgwell, P. J. Valdes, and A. Seale, '"Sunshade world": a fully coupled GCM evaluation of the climatic impacts of geoengineering', *Geophysical Research Letters*, 35 (2008), 1.

[38] Stocker *et al*., *Climate change 2013*, 551.

[39] K. L. Ricke, M. G. Morgan, and M. R. Allen, 'Regional climate response to solar-radiation management', *Nature Geoscience*, 3 (2010), 540. As Ricke *et al*. note, this suggests that "as our understanding improves, serious issues of regionally diverse impacts and inter-regional equity may further complicate what is already a very challenging problem in risk management and governance". In this paper I defend a similar conclusion.

[40] M. MacCracken, 'Geoengineering: worthy of cautious evaluation?' *Climatic Change*, 77 (2006), 237.

[41] A. Jones, J. Haywood, and O. Boucher, 'Climate impacts of geoengineering marine stratocumulus clouds', *Journal of Geophysical Research*, 114 (2009).

[42] A. Robock, L. Oman, and G. L. Stenchikov, 'Regional climate responses to geoengineering with tropical and arctic SO2 injections', *Journal of Geophysical Research*, 113 (2008).

[43] P. J. Irvine, A. Ridgwell, and D. J. Lunt, 'Climatic effects of surface albedo geoengineering', *Journal of Geophysical Research*, 116 (2011).

In addition, SRM does nothing to reduce atmospheric concentrations of CO_2 so if we substitute CO_2 emissions reductions and CDR with such techniques, then the problem of ocean acidification will not be addressed. And to compound these worries, once SRM is underway it may not be viable to turn back, regardless of any negative impacts. This method is designed to impede the global warming effect that would otherwise result from the accumulation of GHGs in the atmosphere so if SRM was ever terminated abruptly or the system failed whilst CO_2 concentrations were still high, there would be a very rapid global warming effect, which would place a severe stress on the adaptive capacities of natural and human systems. Stratospheric aerosol injection also threatens to damage the ozone layer.[44]

Despite the prospect of such negative consequences, SRM in particular is defended as potentially offering a cheap, fast and effective way to address climate change;[45] much to the horror of those who believe that geoengineering is such an ethically troubling suggestion as to be normatively *unthinkable*.[46] Many believe the very idea that we might successfully engineer the Earth system to be hubristic; that any attempts in this direction embody a morally offensive arrogance or see humans trying to play god.[47] One might think that our failure to mitigate climate change, to such extent that geoengineering becomes the better option, would reflect badly on human beings as a species: that this inability to adapt to our natural environment would be evidence of a severe and reckless ethical failing; one that

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[44] Stocker *et al*., *Climate change 2013*, 634.

[45] See, for example, D. W. Keith, E. Parson, and M. G. Morgan, 'Research on global sun block needed now', *Nature*, 463 (2010), 426-7. In a worrying display of ignorance regarding the potentially disastrous impacts of stratospheric particle injection, a recent article in *The Economist* states that this proposal "looks so cheap and technologically convenient that, as far as anyone can tell, there is nothing to stop it being started almost immediately" (The Economist, 'Stopping a scorcher', 23 November 2013. www.economist.com/news/books-and-arts/21590347-controversy-over-manipulating-climate-change-stopping-scorcher (accessed 24 May 2014)).

[46] For discussion of whether geoengineering should be considered unthinkable, see Gardiner, *A perfect moral storm*, 383-5; C. J. Preston, 'Re-thinking the unthinkable: environmental ethics and the presumptive argument against geoengineering', *Environmental Values*, 20 (2011), 457-79.

[47] See C. Hamilton, 'Ethical anxieties about geoengineering' in R. L. Sandler (ed.), *Ethics and emerging technologies* (Palgrave Macmillan, 2013), 440; D. Jamieson, 'Ethics and intentional climate change', *Climatic Change*, 33 (1996), 331-2; J. T. Kiehl, 'Geoengineering climate change: treating the symptom over the cause?' *Climatic Change*, 77 (2006), 227.

might even blight the lives of those responsible, subjecting them to permanent – perhaps irredeemable – moral condemnation.[48]

Notwithstanding these ethical concerns, a major argument for retaining geoengineering as an option of last resort appeals to the idea that at some point in the future, changes in the climate could render geoengineering "the lesser of two evils".[49] Ken Caldeira and David Keith, for example, acknowledge that with geoengineering "the potential for doing harm is great". They claim, however, that we may end up in a situation where geoengineering is expected to be less catastrophic than climate change itself.[50] It might appear that in such circumstances, any ethical reasons against geoengineering would be overridden – and thus that geoengineering should be retained as some sort of insurance policy should such a tragic situation arise.

As Stephen Gardiner notes, this lesser evil argument is somewhat strange given that whether or not humanity will be placed in this tragic situation depends on our current actions;[51] geoengineering could only become the lesser of two evils if we fail to address climate change through GHG emission reductions and less problematic forms of GGR. Given that these alternative means to address climate change are still available, we should be wary that our interest in geoengineering – and the attempt to cast it as the potential lesser of two evils – could be a sign of moral corruption: an attempt by the current generation to subvert the moral discourse in order to avoid the costs associated with climate mitigation, whilst deferring the tragic choice of whether or not to geoengineer to future generations.[52]

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[48] Gardiner, *A perfect moral storm*, 393-4. See also S. M. Gardiner, 'Are we the scum of the earth? Climate change, geoengineering, and humanity's challenge' in A. Thompson and J. Bendik-Keymer (eds.), *Ethical adaptation to climate change: human virtues of the future* (Cambridge, MA: MIT Press, 2012), 241-60.

[49] Jamieson, 'Ethics and intentional climate change', 332-3. See also Gardiner, *A perfect moral storm*, 353-4; S. H. Schneider, 'Geoengineering: Could – or should – we do it?', *Climatic Change*, 33 (1996), 295-6. This reasoning is relevant in particular to SRM, which could have "rapid" effects on the climate – unlike GGR which "would have to be deployed at large-scale for at least one century to be able to significantly reduce atmospheric CO2" (Stocker *et al.*, *Climate change 2013*, 546).

[50] K. Caldeira and D. W. Keith, 'The need for climate engineering research', *Issues in Science & Technology*, 27 (2010), 57. See also Shepherd *et al.*, *Geoengineering the climate*, x.

[51] Gardiner, *A perfect moral storm*, 360-1.

[52] See *Ibid.*, Chapter 10.

Although Gardiner's warning about moral corruption is important, however, it does not serve to refute the lesser evil argument. Those despairing of our lax attempts at mitigation and ongoing social and political inertia may therefore continue to perceive geoengineering as an important Plan B. It might then appear that in order to make the best of this prudent back-up option, research into geoengineering must take place now so that such techniques are "ready at hand (or at least as ready as possible)" *should they ever become necessary*.[53]

Further research into geoengineering can perhaps be defended even to those who are unconvinced by the lesser evil argument. Caldeira and Keith suggest that such investigation could *prevent* dangerous geoengineering from being implemented – or falsely assumed to provide a safety net – because *if* proposals are "unworkable" or pose unacceptable risks, "the sooner scientists know this, the faster they can take these options off the table". Thus, whether the aim is to develop geoengineering as an insurance policy in case of a future tragic situation, or to prevent bad proposals from being deployed, it might appear that "the stakes are simply too high for us to think that ignorance is a good policy".[54]

Discussing the appropriate form of a potential research and development program for geoengineering, Caldeira and Keith concede that some forms of investigation – field testing, for example – are particularly controversial. Further lab-based research into the potential impacts of geoengineering, on the other hand, they claim to be a "no-brainer", supported by many "within and beyond the scientific community".[55] In describing lab-based geoengineering research as a 'no-brainer', Caldeira and Keith seem to imply that seeking to reduce our uncertainty about these interventions through such investigation is morally unproblematic. Ralph Cicerone goes even further than this, defending lab-based geoengineering research by arguing that "freedom of inquiry itself has moral value"; and Dale Jamieson, despite being concerned about the ethical issues raised by geoengineering,

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[53] Caldeira and Keith, 'The need for climate engineering research', 62. Gardiner terms this "the arm the future argument" (Gardiner, *A perfect moral storm*, 354).

[54] Caldeira and Keith, 'The need for climate engineering research', 62. See also Keith *et al.*, 'Research on global sun block needed now'.

[55] Caldeira and Keith, 'The need for climate engineering research', 61.

similarly suggests that "the case for research in almost any field seems obvious and unassailable. It is better to know more than less".[56]

Actually, however, the pursuit of lab-based research into geoengineering raises a number of ethical concerns. Most commonly identified is the problem of moral hazard: the possibility that increased attention to geoengineering could give the false impression that we are insured against dangerous climate impacts, thus undermining efforts to mitigate – or adapt to – climate change.[57] Another worry stems from Gardiner's point that "there are such things as morally bad projects"; for example, those designed to obtain information that would better enable people to commit morally atrocious acts.[58] This possibility suggests that some questions of ethics need to be resolved *before* we can determine whether certain research activities are permissible. If we could conclude, say, that geoengineering would be morally unacceptable in *any* circumstances, then we would have reason to abstain from the investigation of good ways in which to do it.[59] And *even if* geoengineering might be morally permissible in a tragic situation; it is difficult to defend further research on the basis of this lesser evil argument unless one can also give reason to think that it will be possible to establish systems of global governance that can ensure geoengineering will, in fact, be used in a morally permissible way. Thus, it is also necessary for defenders of geoengineering research to address questions of political legitimacy and appropriate, ethically accountable governance for geoengineering activities.[60]

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[56] R. J. Cicerone, 'Geoengineering: encouraging research and overseeing implementation', *Climatic Change* 77 (2006), 224; Jamieson, 'Ethics and intentional climate change', 333.

[57] Jamieson, 'Some whats, whys and worries', 533-4; Shepherd *et al.*, *Geoengineering the climate*, 4. For criticism of the moral hazard argument, see Caldeira and Keith, 'The need for climate engineering research', 62; B. Hale, 'The world that would have been: moral hazard arguments against geoengineering' in C. J. Preston (ed.), *Engineering the climate: the ethics of solar radiation management* (Lanham, MD: Lexington Press, 2012), 113-31; Preston, 'Ethics and geoengineering', 25; Shepherd *et al.*, *Geoengineering the climate*, 45.

[58] Gardiner, *A perfect moral storm*, 351.

[59] This worry holds even prior to determining whether geoengineering could ever be ethically acceptable. Once research programs are initiated, it can be hard to stop the momentum of a project from resulting in development and implementation (Jamieson, 'Ethics and intentional climate change', 333). Thus, if the moral impermissibility of geoengineering is realised only after research has begun, this could prove too late to prevent deployment.

[60] Gardiner, *A perfect moral storm*, 361-3.; S. M. Gardiner, 'Some early ethics of geoengineering the climate: a commentary on the values of the Royal Society report', *Environmental Values*, 20 (2011), 170.

I am not going to take a position, here, on whether geoengineering could ever be morally acceptable. Instead, I will argue that *even if* some form of geoengineering may prove morally acceptable in a tragic situation; in our current circumstances, further lab-based research into the impacts of such techniques could have morally problematic outcomes. As Gardiner notes, superior knowledge doesn't necessarily help you to make the 'right' decision in a normative sense – it may instead help you to act unethically or unjustly. The consequences of such behaviour in the context of geoengineering could be extremely grave and therefore, I will argue, there is reason to think that maintaining our uncertainty about the impacts of geoengineering might be wise for the time being.[61] I will explain why uncertainty may currently be the best policy by first discussing the appropriate form of governance for geoengineering activities, and then explaining how uncertainty could help to promote international agreement on such governance.

The governance of geoengineering

Even if there could be a future state of affairs in which geoengineering would be the lesser of two evils – and thus perhaps the thing to do – we can assume that such a tragic situation would be quite exceptional. There are a much broader range of circumstances in which geoengineering deployment would be both ethically and politically unacceptable: for example, because the situation does not warrant such action, the risks are too great, or the decision to implement lacks legitimacy.

We are therefore in need of some form of international regulatory regime, designed to ensure that geoengineering activities are governed in accordance with fair rules or collective decision-making procedures. However, though efforts are already being made to address the question of global governance for geoengineering[62] – and some existing international

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[61] I thus adopt a position that Rayner claims is common to opponents of geoengineering research: that "it is precisely because the stakes are so high that ignorance is... a good policy" (Rayner, 'To know or not to know?', 13). Cf. Caldeira and Keith 'The need for climate engineering research', 62.

[62] See, for example, the Oxford Principles (S. Rayner, C. Heyward, T. Kruger, N. Pidgeon, C. Redgwell and J. Savulescu, 'The Oxford Principles', *Climatic Change*, 121 (2013), 499-512); the Asilomar Conference Recommendations (Asilomar Scientific Organizing Committee, *The Asilomar Conference recommendations on principles for research into climate engineering techniques* (Washington, DC: Climate Institute, 2010)); the

rules have applicability in this arena[63] – binding international agreement on regulative principles is yet to materialise. It therefore remains the case that "no international treaties or institutions [have] a sufficiently broad mandate to regulate the broad range of possible geoengineering activities", presenting "a risk that methods could be applied by individual nation states, corporations or one or more wealthy individuals, without concern for their transboundary implications".[64]

The importance of fair and effective geoengineering governance is widely accepted, though defenders of lab-based research often suggest that the need for such institutions only arises once field-testing or deployment are considered. The report from the 2010 Asilomar Conference on geoengineering, for example, recommends that new governance mechanisms be created for "large-scale climate engineering research activities that have the potential or intent to significantly modify the environment or affect society" – though not for lab-based research, since this poses "no novel risks or challenges".[65] Caldeira and Keith similarly acknowledge the importance of governance once field-testing is proposed, but hold that lab-based research should be pursued now despite the absence of such institutions.[66] And though Cicerone is particularly resolute concerning the need for governance, suggesting a "moratorium on large-scale field manipulations" until "acceptable

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Solar Radiation Management Governance Initiative (srmgi.org); and the Bipartisan Policy Centre Report (bipartisanpolicy.org/library/report/task-force-climate-remediation-research (accessed 9 June 2014)).

[63] For example, the Convention on Biological Diversity (www.cbd.int/climate/geoengineering/default.shtml (accessed 28 May 2014)); the Convention on Environmental Modification (www.un-documents.net/enmod.htm (accessed 28 May 2014)); and the London Convention and Protocol (imo.org/OurWork/Environment/LCLP/Pages/default.aspx (accessed 28 May 2014)). A problem with most of the legal norms that have relevance in this area is that they "impose little meaningful constraint on geoengineering activities because they are very general and leave states with a huge amount of discretion in deciding what to do" (D. Bodansky, 'The who, what, and wherefore of geoengineering governance', *Climatic Change*, 121 (2013), 542).

[64] Shepherd *et al.*, *Geoengineering the climate*, 60. See also Parson and Ernst, who conclude that "no current international law constrains or regulates the specific activities that might be contemplated in [geoengineering] field research or potential future deployment" (E. A. Parson and L. N. Ernst, 'International governance of climate engineering', *Theoretical Inquiries in Law*, 14 (2013), 320ff.).

[65] Asilomar Scientific Organizing Committee, *The Asilomar Conference recommendations*, 18. See also D. R. Morrow, R. E. Kopp and M. Oppenheimer, 'Toward ethical norms and institutions for climate engineering research', *Environmental Research Letters*, 4 (2009), 2.

[66] Caldeira and Keith, 'The need for climate engineering research', 61-2.

agreements” on ethical and legal issues have been made and a governing body established to oversee such activities, he argues that scientists should support lab-based research in the interim.[67] The idea, presumably, is that lab-based research should proceed in tandem with the design and establishment of appropriate governing institutions, with the moratorium on field testing lifted if and when both are deemed to have achieved adequate results.

The design of governing institutions raises obvious difficulties in that whilst geoengineering could impact all human beings, many of these methods might be implemented unilaterally – by a single state or even a sufficiently wealthy individual or corporation. Acute problems of consent, control, authority, legitimacy, monitoring and enforcement therefore arise. The design of such institutions also raises extremely challenging questions of global justice. As explained above, any given geoengineering intervention is likely to have varied local impacts and will create winners and losers. Even if geoengineering appears likely to reduce harm or death, then: it is quite possible that different people will be harmed or killed as a result of such interventions, creating a profound problem of global distributive justice.

Plausibly, just rules to govern geoengineering activities would, at a minimum, show equal consideration to the interests of all human beings (rather than being designed to serve the interests of some subset of individuals such as, for example, the citizens of a particular state); would provide strong protection for those vulnerable to harm via the testing or implementation of such techniques; and would be the subject of some form of agreement by all affected parties or their representatives. I will not devote much time to the important question of whose agreement would be necessary to render these institutions legitimate; except to note that whilst it is of practical importance that state representatives assent to such global governance,[68] it is clear that other parties should also be involved in the process

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[67] Cicerone, ‘Geoengineering’, 224-5.

[68] As Bodansky points out, given the lack of strong executive powers at the global level, international rules and decision-making procedures “depend primarily on self-compliance by states” (Bodansky, ‘The who, what, and wherefore of geoengineering governance’, 544) – a worry since unilateral implementation by a state (or small group of states) is a particularly troubling geoengineering scenario (*Ibid*., 548-9).

of institutional design.[69] I shall instead focus on how likely it is that the relevant parties will be able to agree on equitable rules of geoengineering governance, which offer adequate protection for the vulnerable.

At first glance, the chances of such agreement would appear slim given the presumed involvement of state representatives; whose primary objective will likely be that of ensuring that governing principles advance their own national interests,[70] and whose track record in addressing climate change has thus far been lacking, to say the least.[71] In the subsequent sections of this paper, I argue that our current circumstances of scientific uncertainty regarding the local and regional impacts of geoengineering interventions could actually have normative value – in the sense that they may be conducive to agreement on fair rules for the governance of activities within this sphere. This suggests that if we want to ensure that just and effective governance is in place prior to any testing or implementation of geoengineering, we may also have to insist – contra the defenders of lab-based research discussed above – that such institutions are created before further investigation into the likely distribution of geoengineering impacts.

The normative value of uncertainty

Though the suggestion that uncertainty can have normative value might appear somewhat unfamiliar, a link between uncertainty and fairness can be found in well-known theories from philosophy, economics and game theory.[72] One of the most prominent uses of this idea in philosophy is found in the work of John Rawls. In *A Theory of Justice*, Rawls attempted to formulate fair principles to govern the institutions of a single society using a

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[69] Indigenous peoples being an important example (see K. P. Whyte, 'Now this! Indigenous sovereignty, political obliviousness and governance models for SRM research', *Ethics, Policy & Environment*, 15 (2012), 172-87).

[70] See E. A. Posner and D. Weisbach, *Climate change justice* (Princeton, NJ: Princeton University Press, 2010), 6.

[71] Concerns along these lines are raised by Gardiner, who worries that "current political inertia on climate change" could well result in part from "a resistance to the kinds of norms of global justice and community that dealing with the problem might suggest" – a problem likely to "infect the search for legitimate geoengineering governance" (Gardiner, 'Some early ethics of geoengineering the climate', 168, 171).

[72] Binmore goes so far as to suggest that uncertainty about the future may help to explain the very origins of our fairness norms (K. Binmore, *Natural justice* (Oxford: Oxford University Press, 2005), Chapter 9).

device called the original position. The original position is a hypothetical situation of choice under uncertainty, where parties representing individual citizens seek agreement on the principles by which their societal institutions will be governed. The epistemic restrictions to which the parties are subjected (termed the "veil of ignorance") conceal all information regarding their personal identity – denying them any knowledge even of probabilities that their individual circumstances will be characterised by certain features. The parties thus do not how the principles agreed to will affect them personally, and in particular cannot rule out that they will be prove to be among the worst-off in the resulting distribution of costs and benefits.[73]

This total uncertainty serves two purposes: first, it aligns the interests of the parties, because in ignorance of their own circumstances they must choose principles on the basis of general facts and concerns alone; and second, it ensures that the principles consented to are fair, because the parties lack any information that they could use to bias the agreement in their own favour. In having to seek agreement on institutions that will best serve their interests *whatever* position in society they may turn out to occupy, the parties are supposed to end up selecting principles that serve everybody's interests equally. In particular, Rawls claims, one can imagine that parties in this situation might well decide that the sensible thing to do is *maximin*: to rank the principles that they can choose between "by their worst possible outcomes", and select the option with the worst outcome that is "superior to the worst outcomes of the others".[74] In this sense, the constraints of uncertainty direct the pursuit of self-interest toward agreement on fair principles:[75] principles that take everybody's interests into account, and protect the least well-off in society by providing them with a "satisfactory minimum". [76]

Though such extreme epistemic restrictions are absent in real-world decision-making, one might think that uncertainty deriving from other sources could have similar effects. For

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[73] J. Rawls, *A theory of justice: revised edition* (Oxford: Oxford University Press, 1999), 118-19.

[74] *Ibid*., 26.

[75] *Ibid*., 127-9.

[76] *Ibid*., 135.

example, James Buchanan and Geoffrey Brennan – in their discussion of the reasons that individuals have for preferring certain political rules – argue that as the *permanence* of such rules increases, a fairness-promoting form of uncertainty may be brought about.[77] The longer a given political rule is intended to be in place, the greater the uncertainty faced by individuals that will be subject to it; in the sense that it becomes harder to predict how that rule will affect them personally, the further into the future they must look. Even citizens in full knowledge of their current circumstances are thus placed in a situation of choice under uncertainty when they seek agreement with one another on *long-term* rules by which they will be collectively governed.

Buchanan and Brennan argue that this effect – which they refer to as the "veil of uncertainty" – provides individuals with reasons of self-interest "to concentrate on choice options that eliminate or minimize prospects for potentially disastrous results". Parties selecting long-standing political rules by which they shall be collectively governed will therefore "tend to agree on arrangements that might be called 'fair' in the sense that patterns of outcomes generated under such arrangements will be broadly acceptable, regardless of where the participant might be located in such outcomes".[78] Robert Goodin and John Dryzek suggest that a similar effect on the selection of political rules may be brought about by circumstances of flux and turmoil. When conditions are unpredictable (for example, in a situation of war), individuals face significant uncertainty not just about the distant future, but also the near future. It thus becomes harder for citizens to ascertain where they will end up in a societal distribution of costs and benefits, with the result that it is in everyone's interests for political institutions to provide the poor with a social safety net.[79]

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[77] G. Brennan and J. M. Buchanan, *The reason of rules: constitutional political economy* (Library of Economics and Liberty, 2000), §10.2.35-8. www.econlib.org/library/Buchanan/buchCv10.html (accessed 21 May 2014).

[78] *Ibid*., §10.2.36-8.

[79] R. E. Goodin and J. Dryzek, 'Risk sharing and justice: the motivational foundations of the post-war welfare state' in R. Goodin and J. LeGrand (eds.), *Not only the poor: the middle classes and the welfare state* (London: Allen & Unwin, 1987), 37-73. Goodin and Dryzek here suggest that this phenomenon could help to explain the substantial growth of the welfare state that took place in a number of countries during and after the Second World War.

Though the underlying uncertainty in each of these cases is different – relating to personal identity, the distant future or the near future – the reason to think that it might have normative value is the same. This underlying uncertainty creates uncertainty about where individuals will be situated in the distributions of costs and benefits resulting from different social and political arrangements, and *this* uncertainty about whether one will be a winner or a loser with respect to such institutions ensures that even self-interested parties have reason to prefer collective rules that possess elements of fairness. The mechanism by which this can take place is quite simple: when parties are denied information that would enable them to identify the rules that will best serve *their own* interests, they have more reason to agree on rules that serve *everybody's* interests – rules, for example, that maximise the position of the least well-off,[80] result in broadly acceptable patterns of outcomes, or provide the vulnerable with a safety net.

Economic theorists interested in climate change have started to consider the possibility that the uncertainty we face in dealing with this problem could have such normative value, using models to explore how "uncertainty and the prospect of learning" affect the incentives for countries to join an international environmental agreement.[81] Though conclusions are only tentative, some of the models so far considered have suggested that uncertainty regarding how the costs and benefits of environmental policies will be distributed could increase the likelihood of cooperation[82] – and that removing such uncertainty might reduce the total amount of welfare that can be obtained by forming an international environmental agreement.[83] As Seong-Lin Na and Hyun Song Shin put it, "cooperation is more difficult to

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[80] Rawls's claim that it is rational for parties in the original position to maximin has been extensively criticised (see, for example, J. C. Harsanyi, 'Can the maximin principle serve as a basis for morality? A critique of John Rawls's theory', *The American Political Science Review*, 69 (1975), 594-606). Whether or not such criticism succeeds, it may nevertheless be the case that less-than-ideally-rational individuals would reason this way, in relevantly similar real-world situations of choice under uncertainty.

[81] C. D. Kolstad and A. Ulph, 'Uncertainty, learning and heterogeneity in international environmental agreements', *Environmental & Resource Economics*, 50 (2011), 391.

[82] C. D. Kolstad, 'Piercing the veil of uncertainty in transboundary pollution agreements', *Environmental & Resource Economics*, 31 (2005), 21-34; S. Na and H. S. Shin, 'International environmental agreements under uncertainty', *Oxford Economic Papers*, 50 (1998), 173-85.

[83] Kolstad and Ulph, 'Uncertainty, learning and heterogeneity', 389.

achieve when the likely winners and losers are known when negotiation takes place".[84] There is thus reason to think that in certain situations, information about environmental impacts could have "negative social value";[85] because by revealing the winners and losers of different environmental policies, it undermines incentives for cooperation.

To summarise this section, then: there is reason to think that when a number of parties seek to establish the arrangements by which they will be collectively governed, uncertainty about how the costs and benefits of potential rules will be distributed could be conducive to agreement on fair institutions. This is because such uncertainty restricts information that parties can use to bias agreements in their own favour. In this situation, self-interested agents are given reason to adopt the common goal of securing their own welfare via institutions that will serve everybody's interests – and, in particular, protect the interests of the most vulnerable. If uncertainty about how the costs and benefits of different environmental policies will be distributed possesses such normative value, however, then research that serves to reduce such uncertainty could have morally problematic outcomes.

Why (effective) governance should come before (certain kinds of) research

The analogy between the examples of decision-making under uncertainty discussed above and the context of institutional choice for geoengineering governance should by now be obvious. In order to ensure that geoengineering research and potential implementation will take the interests of all human beings into account, we need states and other relevant parties to agree on fair rules for the governance of their activities within this sphere. At present, those charged with designing and selecting such rules would have to do so in circumstances of significant uncertainty regarding their position in the distribution of costs and benefits that could result. The reasoning of the previous section suggests that such uncertainty may actually have normative value insofar as it could facilitate agreement on fair rules of governance – and thus that we should be wary of reducing such uncertainty before the necessary institutions have been put in place.

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[84] Na and Shin, 'International environmental agreements under uncertainty', 176.

[85] Kolstad and Ulph, 'Uncertainty, learning and heterogeneity', 401.

This uncertainty about where the costs and benefits may fall, with respect to the rules that could potentially be used to regulate geoengineering activities, derives from a number of sources. For one thing, our world is transforming quickly as a result of climate change and technological progress, which will make it difficult for parties to decide how rules for the governance of geoengineering will affect their interests (or their national interests) over time. An even more significant underlying uncertainty, however, is our extreme scientific uncertainty concerning what the local and regional impacts of any given geoengineering intervention will be. Such uncertainty makes it much harder to determine what form of geoengineering governance will prove to be in any group or individual's best interests, thus creating difficulty for parties seeking to ensure that the benefits of regulatory decision-making are skewed in their own favour.

In particular, it is currently impossible for any parties to rule out the possibility that geoengineering testing or deployment would subject them to severe negative impacts – ones to which they cannot adapt, and for which there is no possibility of rectification. This means that all parties have some incentive to ensure that regulation offers effective protection to those vulnerable to harm. Given the potentially catastrophic outcomes that could result if mechanisms are inadequate to prevent others from implementing geoengineering techniques, parties may even be motivated to maximin;[86] that is, to seek agreement on rules that are likely to maximise the position of the most disadvantaged (where this will presumably include those who stand to be worst off as a result of climate change or potential geoengineering impacts). Alternatively, international actors may at least seek to ensure that geoengineering research and potential deployment is regulated in a way that is designed to promote broadly acceptable outcomes, with protections in place for the most vulnerable.

The claim that further lab-based research into geoengineering is a 'no-brainer' is therefore more problematic than it appears, despite the broad support that such inquiry receives.[87] In

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[86] Rawls suggests that maximin decision-making is most plausible in a situation of choice under uncertainty involving "grave risks" (Rawls, *A theory of justice*, 134).

[87] The Royal Society, for example, states that the development and use of new models to investigate geoengineering should be a high research priority, and identifies the "spatial heterogeneity" of SRM impacts as

the discussion above I briefly introduced the moral hazard objection to geoengineering research, which raises the concern that increased attention to geoengineering could undermine efforts to mitigate and adapt to climate change. I have now identified another worrying potential consequence of further lab-based investigation: by reducing uncertainty about regional and local impacts – thereby helping to identify the winners and losers of potential geoengineering policies and interventions – this research could undermine international cooperation by revealing divergent interests with respect to the regulation of geoengineering. Whether or not freedom of inquiry is good in itself, then; it is important to consider whether pursuing certain avenues of research could have consequences that are bad enough – morally speaking – to outweigh any positive normative value that such inquiry may possess.

If our current circumstances really do instantiate one of those “rare moments of deep and widespread uncertainty” that can serve to promote moral behaviour,[88] then it is important to capitalise on this opportunity.[89] One simple way to do this would be to temporarily extend Cicerone’s proposed moratorium on scientific research to include lab-based studies into the regional distribution of geoengineering impacts – with the moratorium to continue until fair and effective institutions of global governance were established. This is not an unreasonable demand: if the necessary parties cannot prove that they will be able to govern geoengineering in an ethically acceptable manner, then it is risky to engage in research that might lead certain international actors to believe that they would benefit from a particular use of such technology (despite corresponding costs to others). Furthermore, this demand is particularly hard to reject with respect to techniques that are viewed as a lesser evil, to be used as an option of last resort. Such interventions are not expected to be necessary in the near future, so halting research until adequate governance mechanisms have been established should not lead to irrecoverable delays.

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a particular area in which further study should be conducted (Shepherd *et al.*, *Geoengineering the climate*, 52-4).

[88] Goodin and Dryzek, ‘Risk sharing and justice’, 66.

[89] Rayner similarly suggests that “once research gets under way (if it does), then... debates over the science will displace the debate over the values”, meaning that we currently have “a moment of clarity” that we should attempt to capture and use to stimulate discussion about the kind of world that we want to inhabit (Rayner, ‘To know or not to know?’, 15-16).

As Gardiner has argued, the problem of climate change presents the current generation with a moral challenge that is perhaps unprecedented in its global scope, intergenerational nature, and the inadequacy of our current normative theories for dealing with many of the questions that it raises. In these testing circumstances, we ought to be on the lookout for signs of moral corruption; for signs, that is, that those in a position of power (the affluent and current generations) are seeking to obscure their attempts to shift the costs of climate change onto those who are relatively weak (the poor and future generations).[90] Gardiner's warning about moral corruption should lead us to be vigilant if certain parties appear to be trying to delay or undermine the establishment of strong regulatory institutions for geoengineering governance. The argument presented in this paper suggests that those attempting such obstruction could be motivated by the desire to find out more about the likely impacts of geoengineering before international rules are put in place, so that they can seek to bias any governing agreements in their own favour; or, even, retain the option of geoengineering deployment in pursuit of their own benefit, unhindered by strong regulatory principles.[91]

Conclusion

Geoengineering is generally conceded to be an ethically problematic response to the problem of climate change, even by those who argue that we must retain this alternative as an option of last resort and that scientists should therefore continue to engage in geoengineering research so that we can be prepared for this eventuality. Fair and effective governance is also widely accepted to be essential prior to any testing or implementation of these techniques, in order to ensure that such actions are legitimate and morally acceptable.

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[90] Gardiner, *A perfect moral storm*, 7-8.

[91] See, for example, the argument given in L. Lane, 'Climate engineering and international law: what is in the national interest?' *Proceedings of the Annual Meeting (American Society of International Law)*, 105 (2011), 525-8. Lane here defends further geoengineering research on the basis that it will enable the US to identify what policies are in its national interest; and rejects any governance or international law *at all* so as to preserve "America's [*sic*] freedom of action" within this sphere (*Ibid*., 527-8).

In this paper I have given reason to think that as uncertainty about the international distribution of geoengineering impacts is reduced, our chances of establishing fair and effective institutions of global governance will diminish along with it. Uncertainty about the impacts of geoengineering methods currently makes it hard to assess who the winners and losers will be, with respect to the different forms of regulation that might be adopted. This creates a barrier to the exercise of self-interest and gives all parties to any governance agreement a reason to be concerned with the plight of those who would bear the costs of weak or inequitable regulation – because for all they know, they could prove to be among those most vulnerable to the potentially catastrophic impacts of geoengineering. Thus, even lab-based research into the impacts of geoengineering interventions could be more ethically problematic than scientists recognise. If such research leads a particular state or other party to conclude that they are a likely winner with respect to a given geoengineering intervention, any incentive to sign up to fair and effective governing institutions will be severely diminished – just as their temptation to pursue this option will become dangerously enhanced.

Advocates of geoengineering are often accused of arrogance for supposing that human beings can control the climate, but similarly worrying appears to be the assumption that scientists can control what is done with the results of their research. Whether or not geoengineering could turn out to be the lesser of two evils in a certain, tragic future scenario – it is not clear why one would think that this is the only situation in which international actors might decide to implement such techniques. Caldeira and Keith are correct that research into geoengineering may ultimately suggest that all such proposals pose unacceptable risks to sections of human society. What may prove hubristic, or simply naive, is the assumption that scientists will be able to take these unacceptably risky options off the table, should their research imply that such techniques would simultaneously benefit parties with the capacity to geoengineer – parties who may decide that the potential benefits to themselves render the risks to others acceptable after all.