Daniel Bodansky

The Who, What, and Wherefore of Geoengineering Governance[1]

Arizona State University
1100 S. McAllister Ave.
Tempe AZ 85287
Daniel.Bodansky@asu.edu
480-607-2251

Abstract

The potential of geoengineering to reverse global warming rapidly and cheaply makes it alluring to groups across the political spectrum. But geoengineering also poses significant risks and raises the specter of technology gone awry. This article analyzes the basic governance issues raised by geoengineering, including the possible functions, forms, objects and agents of governance. It then explores these issues by focusing on four scenarios of particular concern: inadequate research funding, premature rejection, unilateral individual action, and unilateral state action.

Keywords: international law, governance, geoengineering

[1] Parts 1 and 3 are drawn from an earlier discussion paper, "Governing Climate Engineering: Scenarios for Analysis (Harvard Project on Climate Agreements 2011).

1 Introduction

How much are we willing to bet that countries will succeed in preventing dangerous climate change by cutting their emissions of carbon dioxide and other greenhouse gases? The IPCC estimates that global emissions would need to go down by 50-85% from 2000 levels by 2050 in order to limit global warming to 2° C – the goal adopted by states at the Copenhagen conference (IPCC 2007, Table SPM.5). But global emissions continue to rise at a rapid rate, and are now 30% higher than in 2000.[2] Most of the discussions of future warming focus on the effects of doubling carbon dioxide levels from pre-industrial times to 550 ppm. But the implications of this scenario, although themselves dire, may be far too optimistic, since our current emissions trajectory suggests that CO_2 levels may triple or even quadruple rather than double by the end of the century (NAS 2011, 60). The resulting climate change would be in the neighbourhood, not of 2-3^o C, as most discussions assume, but more than 5^o C (or 9^o F) (Sokolov 2009). Add to this the possibility of climate "surprises," in which the climate system crosses some threshold, resulting in "large, abrupt, and unwelcome" changes (NAS 2002, 1), and our current predicament becomes even more alarming.

Thus far, the major international response to the climate change problem has been to negotiate international limits on national greenhouse gas emissions. But the results, to date, have been meagre. The Kyoto Protocol's initial commitment period covers less than 30% of global emissions for a five-year period ending in 2012, and has not stopped global emissions from continuing to grow due to increased emissions in the United States, China, and other countries that don't have Kyoto targets. Unless the Kyoto Protocol can be either dramatically increased in scope or replaced by a new, more comprehensive agreement, global emissions will continue to rise as China and other major developing countries industrialize.

This grim outlook has led many to take a second look at geoengineering solutions to climate change. In the past few years alone, the Royal Society (2009, 2011), the General Accounting Office (2010), and the National Academy of Sciences (NAS 2010) have all issued reports addressing geoengineering; several books (Fleming 2010; Goodell 2010; Kintisch 2010) and countless articles have appeared in the popular press; and numerous conferences and workshops have been organized, including the 2010 Asilomar Conference on Climate Intervention Technologies and an IPCC workshop in 2011 (IPCC 2011).

Geoengineering is of interest to groups across the political spectrum. On the one hand, it is attractive to climate sceptics, since it reduces the need to take

[2] According to Olivier (2011), Table A1.1, global emissions were 25.3 Gt in 2000 and 33 Gt in 2010.

action now. If geoengineering were possible, then even if climate change predictions turn out to be true (which sceptics think unlikely), we could still respond through geoengineering. On the other hand, geoengineering is also of interest to environmentalists, as a means of averting catastrophic climate change, should efforts to reduce emissions fall short. Geoengineering could also prove attractive to politicians (although few have shown much interest thus far[3]), because it allows them to avoid making difficult decisions now. And geoengineering is seductive to economists, because compared to emissions mitigation or adaptation, some geoengineering technologies appear astonishingly cheap (at least from a program implementation standpoint, leaving aside the potential environmental risks) – in particular, injecting sulfur aerosols into the stratosphere to block incoming sunlight (Barrett 2008). If geoengineering in fact proves effective in reducing the global temperature, then it might well be the most efficient way to address climate change – much cheaper than reducing emissions.

Geoengineering has an additional allure, at least for those who are beginning to despair of effective collective action: its low costs and global effects give individual countries the ability – and potentially the incentive – to "solve" the climate change problem unilaterally. As David Victor notes, this "turns the politics of climate protection upside down" (Victor 2008, 323). Reducing greenhouse gas emissions is an example of what economists call an "aggregate effort" public good: it depends on collective action by the world's big emitters, a prisoners' dilemma problem that has thus far proved impossible to solve. In contrast, geoengineering is a "best shot" collective good that could potentially be supplied by an individual country (Barrett 2007).

Of course, the potential ease with which geoengineering could be undertaken either collectively or individually also makes it scary. The prospect of taking action to remake the planet brings to mind, for some, images of technology gone awry – of climate scientists acting like Dr. Frankenstein or Dr. Strangelove (Hamilton 2010). The hope is that the effects of geoengineering would be mostly positive. But geoengineering also poses risks. Some are known – such as the potential effects on the ozone layer or regional weather patterns. But the unknown, "impossible-to-predict surprises" are what worry many people most (Lempert et al 2011). And the potential for individual countries to undertake geoengineering unilaterally only exacerbates these fears.

For environmentalists and most scientists, geoengineering is definitely Plan B – a “stop-gap” if efforts to mitigate climate change fall short (Barrett 2008, 47). For them, reducing greenhouse gas emissions should be the primary policy, and geoengineering is suspect to the extent it detracts from emissions mitigation. But for climate sceptics and some economists, geoengineering may represent

[3] An exception is the UK House of Commons Science and Technology Committee (2010).

Plan A – that is, the preferred international approach (*see, e.g.,* Teller et al. 2003).

Whether seen as Plan A or B, geoengineering raises major political and ethical issues (Gardiner 2010) – and hence major governance challenges. Who should decide whether and how to engage in geoengineering? Should individual countries be allowed to weigh the potential benefits and risks on their own? Or should geoengineering require collective decisions and, if so, what international body should have this responsibility? What limitations, if any, should be placed on individuals to prevent them from undertaking geoengineering? And how should the international community address attempts by individual states to engage in geoengineering?

2 Some basic issues

2.1 What is the purpose of geoengineering governance?

Geoengineering governance could have several potential goals. If we are concerned to keep the geoengineering option open, international governance might aim to facilitate or even promote geoengineering research, so that we have a better understanding of the feasibility, costs, and benefits of different geoengineering techniques. In contrast, if we are concerned about the potential risks of geoengineering, then geoengineering governance might aim to impose limits on geoengineering or to collectivize the decision-making process, in order to prevent actors from making decisions that might have serious, even catastrophic, consequence for others. Governance is needed, in the first case, to ensure sufficient geoengineering and, in the second, to avoid too much.

2.2 What forms can geoengineering governance take?

Although definitions of governance vary, the essence of governance is to make decisions for a collective. The decisions may be general rules intended to guide behavior, or very specific decisions related to a specific case.

2.2.1 General rules

For the most part, international governance operates through the elaboration of general rules – rules to protect the ozone layer, limit the use of force, promote free trade, and so forth. Although there is, as yet, no international agreement on geoengineering, a number of existing international rules are potentially relevant to one or more forms of geoengineering, including:

- general principles such as the duty to prevent transboundary harm, the precautionary principle, and the principle of inter-generational equity;
- treaty norms such as the prohibition on the use of environmental modification techniques for military or other hostile purposes

(ENMOD Convention, art. I), the duty to protect and preserve the marine environment (UN Convention on the Law of the Sea, art. 192), and the requirement to take "appropriate measures" to minimize the adverse effects of mitigation measures on public health and environmental quality (UNFCCC, art 4.1(f));[4]

- decisions by international institutions, such as the decisions by the parties to the London Convention and the Convention on Biological Diversity (CBD) to limit ocean fertilization activities (London Convention 2008, para. 8; CBD 2010, para. 8(w));
- rules developed by non-governmental actors, such as the Oxford Principles for Geoengineering Governance (Rayner et al 2012).

2.2.1.1 Self-implementation

How might general rules such as these constrain geoengineering activities? One possibility – on which international law primarily relies – is self-implementation and self-compliance by states. Political scientists often discount the role of voluntary compliance (Downs et al 1996), while scientists tend to express greater concern about international pronouncements like those made pursuant to the London Convention or the CBD. But the truth lies somewhere in between. The degree to which international rules are effective in influencing behavior varies, depending on a number of factors:[5]

Legal form – The assumption behind most treaty negotiations is that binding agreements have a greater influence on state behavior than non-binding (soft law) instruments. So, all other things being equal, rules found in binding agreements such as the UNFCCC, UNCLOS and ENMOD should have a greater influence on behavior than non-binding instruments such as the decisions of the parties to the London Convention and CBD on ocean fertilization. The relationship between legalization and effectiveness is not invariant, however, and soft law rules can also sometimes be effective (Shelton 2000). Indeed, in some circumstances, non-binding instruments may be more effective than binding ones, by allowing states to adopt clear and ambitious commitments (Victor et al 1998).

Precision – Precise rules provide greater guidance for behavior than general rules, which can be interpreted in self-serving ways. Most of the existing legal norms relating to geoengineering impose little meaningful constraint on geoengineering activities because they are very general and leave states with a

[4] For a detailed analysis of the existing international rules relevant to geoengineering, see Royal Society (2011), Appendix 3.

[5] The following material is adapted from Bodansky (2010), at 264-65.

huge amount of discretion in deciding what to do. The precautionary principle, for example, admonishes countries to be cautious in the face of scientific uncertainty. The problem is that, in the case of geoengineering, failure to take action could also result in irreversible and catastrophic harm due to global warming, so it is unclear which way the principle cuts. The dilemma brings to mind a cartoon showing one politician confessing to another: "I'm inclined to do the cowardly thing. I just don't know what it is." By contrast, the decisions by the parties to the London and Biological Diversity Conventions, although not legally binding, may have a bigger direct effect on geoengineering activities because they delineate more precisely what states can and cannot do – for example, by imposing a moratorium on climate-related geoengineering activities that may affect biodiversity, except for small-scale scientific research studies (CBD 2010, para. 8(w)).

Legitimacy – States may be more likely to feel an obligation to comply with a rule that results from a process they regard as legitimate, for example, because it is broadly participatory or tends to produce good results.

Incentives to violate – International rules are only one of many factors that influence a state's behavior, and may be overwhelmed by other factors such as self-interest. The greater the costs imposed by a legal rule, the greater the incentive for a state to violate it. For this reason, procedural rules that impose few costs, such as a requirement to undertake environmental impact assessments, may be more effective than a complete prohibition on geoengineering activities, which a state would have a huge incentive to violate if it faced catastrophic climate change.

Ability to comply – Even if a state is willing to comply with an international rule, it may not be able to comply, due to limited resources or capacity. For example, a prohibition on geoengineering activities by private actors might be difficult for a state to enforce if it has limited administrative capacity to monitor and control private conduct.

2.2.1.2 Implementation by sub-national or private actors

Apart from self-compliance by states, a second possible way that international rules might constrain geoengineering activities is by influencing the behavior of sub-national or private actors. The Kyoto Protocol's emissions targets, for example, were rejected by the United States government; but the Protocol has influenced the behavior of cities within the United States, many of which have adopted the Kyoto Protocol's targets. Similarly, decisions by international institutions on geoengineering, even if directly applicable only to states, could have a significant influence on other actors – for example, by affecting decisions by national funding agencies or by dissuading scientists from engaging in geoengineering research in the first place.

2.2.1.3 Structuring the terms of the political debate

Finally, international rules on geoengineering could affect behavior indirectly by structuring the terms of the political debate about geoengineering, both within countries and internationally. General principles such as the duty to prevent transboundary and the precautionary principle may not exert much influence in directly steering state behavior. But, regardless, they provide an evaluative standard that other states and non-governmental actors could use to critique geoengineering activities (Bodansky 2010, 201-03).

2.2.2 Case-by-case decision-making

International governance can be exercised not only by promulgating general rules, but also by case-by-case decision-making, either *ex ante* to authorize an activity or *ex post* to resolve disputes and determine legal liability. Under the UN Charter, for example, decisions to use military force require the advance approval of the Security Council, except in cases of self-defence. Similarly, decisions to engage in geoengineering could be internationalized through the establishment of a multilateral authorization process.

At the national level, permitting processes are common for risky activities such as selling a new drug or building a new power plant. Usually, international institutions do not make case-by-case decisions themselves. Instead, they outsource the decision-making process to states by requiring them to establish a permitting procedure. For example, the 1972 London Convention requires parties to establish a permitting process for the dumping of wastes at sea. Similarly, the 1973 Convention on International Trade in Endangered Species requires parties to issue permits for imports and exports of endangered species.

To the extent that geoengineering activities receive governmental funding, then case-by-case governance could be exercised *ex ante* through funding decisions. By contrast, private activities would need to be subject to some kind of permitting system. Case-by-case control of geoengineering could also be exercised *ex post* through the establishment of a liability or enforcement regime, which reviewed the effects of particular geoengineering decisions and awarded damages.

Governance by general rules and by case-by-case decisions are not mutually exclusive; they are closely related and often go hand-in-hand. The predicate for establishing an international approval process for particular geoengineering activities would be a general rule prohibiting states from engaging in geoengineering unilaterally. Moreover, since the international system still lacks strong executive powers, international decisions, like general rules, depend primarily on self-compliance by states. They operate much like a very precise rule that determines the outcome of an individual case. Because it is

comparatively clear what states must do to comply with a decision, violations are obvious and have higher reputational costs.

2.2.3 Other governance functions

Whether geoengineering governance is exercised through case-by-case decisions or the promulgation of general rules, it requires information about what is going on – who is engaging in what kinds of geoengineering, where, and with what effects. So systems of monitoring, reporting and verification are important aspects of geoengineering governance.

Broadly conceived, governance can also be exercised through the provision of funding or other forms of assistance. The World Bank, for example, plays an important role in global governance. International institutions that provide funding for, rather than regulate, geoengineering activities should also be seen as an aspect of geoengineering governance.

2.3 Who should exercise these governance functions?

The answer to the question, "who should govern?" depends on the functions and forms of governance. If the function of governance is to ensure adequate levels of geoengineering research, then governance might be exercised by a relatively small group of countries with the capacity to engage in research (Benedick 2011). In contrast, if the function of governance is to limit the potential risks of geoengineering, then the scale of governance should arguably match the geographic scope of the externalities, so that all those who might be affected by geoengineering have a seat at the table. Broad participation, however, can have costs as well as benefits. Although it may enhance the legitimacy of geoengineering governance, it may also diminish its effectiveness by making agreement more difficult (Royal Society 2011).

Should geoengineering governance be exercised by a single institution or by multiple actors? To the extent that different geoengineering techniques raise different issues, this suggests the desirability of a more decentralized approach. Such an approach could also take advantage of existing international institutions with mandates relevant to geoengineering: for example, the London Convention and CBD with respect to ocean fertilization, and the Montreal Protocol and Long-Range Transboundary Air Pollution Convention with respect to stratospheric aerosol injection.

Separation of powers principles also suggest the desirability of assigning different governance functions to different institutions. For example, a broadly-inclusive international institution might be appropriate for the development of general rules regarding geoengineering, since standard-setting involves value choices. In contrast, the application of these rules to individual cases might be addressed by a smaller group with technical expertise or by national decision-makers. Meanwhile, non-governmental groups could play a role in monitoring

functions, as they do already under some international environmental agreements such as the Convention on International Trade in Endangered Species (CITES).

2.4 Over whom should governance be exercised?

Since geoengineering might be undertaken by states or by non-state actors such as companies, scientists, or wealthy individuals, governance is needed of both state and non-state actors. In principle, international rules on geoengineering could apply directly to non-state actors, as is true of international criminal law. But, ordinarily, international law regulates the conduct of states and applies to individuals only indirectly, through national implementing legislation. For example, the UNFCCC, UNCLOS, ENMOD, CBD, and London Convention all apply to states rather than private actors, and the same is true of decisions made by the parties to the London Convention and CBD on ocean fertilization. To the extent that regulation of scientists or private companies is necessary to effectuate any of these international rules, it is up to states to do so.

States have jurisdiction over activities within their territory, so regulating private conduct within a country is unproblematic, at least as a legal matter. For scientific research projects that receive government support, regulation could also be exercised indirectly through funding decisions. In contrast, activities that take place in areas beyond the limits of national jurisdiction, such as the high seas or the stratosphere, raise more difficult jurisdictional questions. Ships on the high seas are subject to the jurisdiction of their flag state. But given the possibility of reflagging vessels in states with lax regulation, other jurisdictional bases may be appropriate. For examples, international law permits geoengineering activities on the high seas to be regulated by an actor's state of nationality or by the port from which the ship departed.[6]

3. Scenarios

To see how these various issues might play out, it is useful to consider specific scenarios for geoengineering research and deployment. A comprehensive examination of the potential scenarios is beyond the scope of this paper. Instead, I consider four scenarios that have received some attention in the literature and that illustrate the range of issues involved.

The scenarios vary along a number of different dimensions. First, they raise different concerns and hence different governance challenges. In the first two

[6] The 1972 London Convention already requires parties to regulate ocean dumping by ships loaded in their territory (Art. VI(2), and general principles of international law allow states to regulate activities by their nationals anywhere in the world.

scenarios, the problem is too little geoengineering, either because of knee-jerk rejection or inadequate funding, so the governance challenge is to enable and facilitate geoengineering. In the latter two scenarios, the problem is too much geoengineering, either by individuals or governments, so the governance challenge is to limit or prohibit it.

Second, the four scenarios involve different "regulatory targets." Some involve scientists, who are relatively easy to regulate; others involve more difficult regulatory targets, such as rogue individuals or states.

3.1 *Inadequate Research Funding*

One near-term scenario is that geoengineering research funding will continue to be limited, leading to inadequate levels of research about the pros and cons of different geoengineering techniques. Currently, funding for geoengineering research is very low. Although cost might not be an issue if a country were facing a climate emergency, this is not the perception now, when geoengineering is still seen as, at best, a second or third choice option. The 2009 Royal Society report found that "little research has yet been done on most of the geoengineering methods considered, and there have been no major directed programmes of research on the subject." A 2010 GAO report found that U.S. government agencies were spending $100.9 million in geoengineering-related funding, but only about $1.9 million involved direct investigations of a particular geoengineering approach, a miniscule sum. Government funding of geoengineering research is so low that a significant part of the research funding to date has come for a private gift by Bill Gates.

Limited research is a problem because, if and when geoengineering becomes necessary, we will lack knowledge about which approaches are more or less effective and more or less dangerous. So there will be a greater chance that geoengineering efforts will fail or cause serious collateral damage. As Virgoe notes, "ignoring geoengineering today, and only considering it when all else has failed, is a recipe for bad, politics-led decision-making" (Virgoe 2009, 117). What we need instead is a research program that assesses the efficacy, risks and costs of different geoengineering approaches, in order to allow better decisions to be made about "whether, when and how to use" geoengineering technologies (Bipartisan Policy Center Task Force 2011, 29).

The rationale for international governance in this scenario is to encourage national spending, develop cost-sharing arrangements, and incentivize private investment. What role might international institutions play in promoting geoengineering research? In some cases, where the costs of geoengineering technologies are high, an international burden-sharing arrangement might be helpful, like those to develop the space station or the Large Hadron Collider at CERN (Barrett 2007). In addition, international institutions could play an

important role in helping to remove the taboo against geoengineering prevalent in the scientific community and to legitimate research activities.

3.2 *Premature Rejection*

A second near-term scenario that has received considerable attention is that the prospect of geoengineering raises public alarm, leading to a moratorium or ban on geoengineering activities (Victor 2008). Like the first scenario, the problem here is inadequate research, but in this case, the cause is over-regulation rather than inadequate funding.

Moratoriums and bans have the attraction of simplicity. They create bright-line rules, and thus avoid the need for complex, ongoing decision-making, which may be beyond the institutional capacity of the international community, particularly in cases of significant uncertainty. Examples of moratoriums or bans in international law include the moratorium on commercial whaling, adopted by the International Whaling Commission in 1982, the moratorium on Antarctic mineral activity imposed by the Antarctic Environment Protocol, and the bans on genetically-engineered foods imposed by European countries in the 1990s. As the whaling case illustrates, unless moratoriums are time limited, they can be very difficult to lift, even after scientific uncertainties are resolved and management is feasible.

Under the premature rejection scenario, the problem is too much geoengineering governance rather than too little. A moratorium or ban on geoengineering adopted by an international institution such as the CBD or the London Convention would not directly bind scientists; instead, it would apply to states. But it could nevertheless chill scientific research by influencing government research funding decisions, prompting governments to impose domestic restrictions on research, or encouraging professional attitudes hostile to geoengineering research. Making matters worse, a moratorium would likely have the biggest effect on countries that tend to be risk averse and that would have pursued geoengineering research most responsibly, helping to establish sound research norms. A moratorium could thus have the perverse effect of leaving the field of geoengineering research to less responsible countries that ignore the moratorium and engage in riskier activities (Victor 2008).

In this scenario, the task of international governance is very different than in the first scenario, where governance was needed to encourage national spending, develop cost-sharing arrangements, and incentivize private investment. Here, the governance challenge is to forestall drastic regulation through more moderate regulation that promotes transparency, public participation, and independent assessments. In essence, the role of governance is to bolster public confidence that geoengineering will be pursued in a responsible manner, in order to prevent a backlash against it. In part, this

requires establishing a governance structure that engenders trust, but it also requires avoiding geoengineering projects that seem reckless or, even worse, go awry.

Guidelines or regulations on geoengineering research could be adopted by an international organization such as the World Meteorological Organization or the Intergovernmental Oceanographic Commission of UNESCO. But getting agreement among states may be difficult, so self-regulation by scientists – for example, through the development of research codes of conduct – may be more feasible, at least initially. Already, this process of self-regulation has begun, with the development of the Oxford Principles on Regulation of Geoengineering by a group at the University of Oxford (Rayner et al 2012), and the organization of the Asilomar Conference in March 2010. Informal norms developed by scientists, social scientists, philosophers and lawyers are not legally binding, but nonetheless, they could help inform national geoengineering programs[7] and eventually became the basis for an inter-governmental code of conduct or formal agreement on responsible geoengineering research. Ultimately, their success in forestalling more drastic regulation hinges on their public credibility, rather than on their legal status or source.

3.3 "*Greenfinger*"

A third scenario is what David Victor has dubbed the "Greenfinger" scenario, in which a rich private actor undertakes geoengineering on his or her own (Victor et al 2009). The allusion to the villain in James Bond's *Goldfinger* suggests that geoengineering is seen here as a global public bad rather than a global public good. Accordingly, the task of governance is not to enable or encourage geoengineering to proceed, as in the first two scenarios, but rather to prevent private actors from engaging in geoengineering on their own.

In certain respects, this problem is similar in structure to combating terrorism (although the goals and methods of geoengineering and terrorism are, of course, very different). In both cases, individuals have the capacity to do things with huge, and potentially damaging, effects for the global community. The international governance challenge is hence to control private conduct. In significant part, this is a problem of international law enforcement cooperation. In the case of terrorism, law enforcement cooperation has been effectuated through various treaties and Security Council resolutions that require states to criminalize terrorist acts, investigate and punish terrorists, and cut off their access to financing. Similarly, states could develop an international regime for

[7] In urging the establishment of a federal research program on geoengineering, the Bipartisan Policy Center Task Force on Climate Remediation recommended a number of guidelines, which emphasize the importance of outside oversight, transparency and international coordination. Bipartisan Policy Center Task Force 2011, at 13-14.

geoengineering that requires parties to control geoengineering activities under their jurisdiction, and that clarifies which states have jurisdiction over activities outside of national territory (for example, on the high seas or in outer space).

The example of terrorism also illustrates that, if the threat of private geoengineering seemed sufficiently grave, states might take military action rather than limiting themselves to a law enforcement approach. In this regard, geoengineering may in some ways be an easier problem to address than terrorism, since the harms from geoengineering wouldn't be inflicted by a single, difficult-to-prevent act, but rather by ongoing activity that could potentially be stopped before it caused significant damage. If an extremely rich individual, for example, were to build a fleet of ships to engage in cloud whitening, this would presumably be easy to detect and stop, if necessary by seizing the ships (although the same may not be true of stratospheric aerosol injection, which may prove more difficult to monitor).

3.4 *Unilateral or minilateral state action*

A final, more troubling scenario involves an individual country or a small group of countries undertaking geoengineering without international approval – the United States or China acting unilaterally, for example, or a coalition of small island or African states acting jointly. Because some types of geoengineering appear astonishingly cheap – in particular, injection of aerosols into the stratosphere to reflect sunlight – unilateral geoengineering may be within the capacity of some individual states.[8] As noted earlier, this would make geoengineering an example of what economists call a "best shot" global public good, which could be supplied by a single country acting alone.

The "best shot" characteristic of geoengineering is simultaneously its most comforting and its most troubling feature – comforting because it means that global warming could be solved without the need for international cooperation; troubling because a single country could conceivably have the capacity to wreak havoc on the entire globe. For this reason, unilateral geoengineering by states has attracted probably more attention than any other geoengineering scenario.

Under what conditions might a state decide to undertake unilateral geoengineering? Since doing so would likely provoke a strong reaction by other states, some commentators argue that unilateral geoengineering is unlikely (Horton 2011), and most assume that states would undertake it, if at all, only *in extremis* (Virgoe 2009; Lempert et al 2011). But given the propensity of states to act unilaterally in other arenas where their survival is at stake, even at the risk of international conflict, the possibility of unilateral geoengineering needs to be

[8] The Bipartisan Policy Center Task Force on Climate Remediation (2011) estimates that perhaps a dozen states have the technological and economic capacity to deploy stratospheric aerosol injection techniques.

taken seriously. Moreover, while it seems plausible that a state would be willing to undertake geoengineering only as a last resort, there is no bright line between normal and extreme situations. In the movies, climate catastrophes may be so dramatic as to leave no doubt, but in the real world catastrophes are usually less obvious. Given the difficulty of attributing particular weather events to global warming, people are likely to disagree about whether it is time to press the panic button and resort to geoengineering. So there is likely to be considerable squishiness about the circumstances that warrant geoengineering. Indeed, it is possible that some states might decide that geoengineering presents a more desirable option than emissions cuts and decide to undertake geoengineering without any triggering, catastrophic event (Lempert et al 2011).

The unilateral-state-action scenario is more troubling than the Greenfinger scenario because it would be considerably more problematic to stop a state from acting than an individual. The problem is akin to preventing states from using military force unilaterally, which international law has not been very successful in doing. Plus, if one state proceeded with climate engineering, other states might take retaliatory measures – including measures to warm the climate back up. So there is a significant potential for inter-state conflict.

How might an international regime address the problem of unilateral state geoengineering? One possibility would be to internationalize decision-making about whether to deploy geoengineering, in what amounts, and by whom (Virgoe 2009, 114; Barrett 2008, 53; Lin 2009). This is the approach that the UN Charter uses with respect to the use of force: it takes decision-making authority away from individual states (except in cases of self-defense) and gives it to the Security Council. Similarly, decisions about geoengineering could be delegated to an existing institution like the UNFCCC or to a newly-created one.

Proposals to create an international geoengineering organization with decision-making authority face two difficulties, however. First, there seems little prospect that states would turn over decision-making about geoengineering to an international body. Certainly this is true of the United States, where it is almost impossible to imagine 67 Senators agreeing to give an international organization control over United States' decisions about geoengineering. Second, even if such an organization could be established, it is hard to see how it would be able to enforce its decisions. In the parallel case of the Security Council, the Security Council lacks the power in most cases to prevent states from using force unilaterally, so states continue to do so when they have a sufficient national interest. There is no reason to think that an International Geoengineering Authority would be any more successful in curbing unilateral action when countries feel that their vital national interests are at stake.

A more promising alternative might be to establish an international regime that seeks to cabin rather than to prevent unilateral state action. For example, an international instrument could create a scientific advisory body like the IPCC

that assesses geoengineering techniques in order to promote science-based decisions (Benedick 2011). It could also establish a consultative mechanism that encourages states to notify and consult with one another about planned geoengineering activities. States would have an incentive to do so in order to avoid uncoordinated geoengineering initiatives that might undermine one another—and that might even generate interstate conflict (Horton 2011). An international regime might also address some of the subsidiary issues raised by geoengineering, such as liability for damage resulting from geoengineering activities, although this would be considerably more difficult politically.

4 Conclusion

When we think about geoengineering governance, we are in a highly speculative area. The kinds of governance that might emerge will depend on a wide range of often unpredictable factors.

Further complicating the issue, governance of geoengineering is not a one-dimensional challenge. It could involve many different tasks: developing norms to guide scientific research, allocating jurisdiction among states to regulate individuals, elaborating rules that constrain state behavior, and establishing procedures to limit conflict among states. Some of these governance tasks seem more do-able than others. Developing a minimal governance structure to guide geoengineering research seems comparatively easy, as does providing some modest research funding. In contrast, limiting geoengineering deployment would be more difficult. The problem posed by individuals could potentially be addressed in the same way as terrorism: through treaties that address jurisdictional issues and require states to proceed against individuals subject to their jurisdiction. But developing a governance structure that limits geoengineering by states will be very difficult.

Given the challenge of negotiating a new treaty on geoengineering, governance of geoengineering is more likely to develop, in practice, through the extension of existing treaty regimes to cover various types of geoengineering than through the adoption of a single comprehensive regime – for example, through the application of the London Convention to ocean fertilization, or the Montreal Protocol to stratospheric aerosol injections. This makes sense, partly because different types of geoengineering raise very different kinds of issues. But the dispersion of authority to different institutions will make it more difficult to consider geoengineering in an integrated manner. Suggestions to do so under the banner of the UNFCCC (for example, Lin 2009) are implausible, since the UNFCCC is seen as dysfunctional by many countries, and few trust its ability to make decisions.

Geoengineering raises understandable fears about technological hubris. Virtually everyone who studies geoengineering hopes that it will not prove necessary. But with global emissions continuing to rise, and little prospect of

reversing that trend anytime soon, we are not living in a world where we can assume the best. We are living in a world where we must prepare for the worst.

References

Barrett S (2007) Why Cooperate? The Incentive to Supply Global Public Goods. Oxford University Press, Oxford

Barrett S (2008) The Incredible Economics of Geoengineering. Environ Resour Econ 39: 45-54

Benedick RE (2011) Considerations on Governance for Climate Remediation Technologies: Lessons from the 'Ozone Hole'. Stanford J Law Sci Policy 4: 6-9

Bipartisan Policy Center Task Force on Climate Remediation Research (2011) Geoengineering: A National Strategic Plan for Research on the Potential Effectiveness, Feasibility, and Consequences of Climate Remediation Technologies. Bipartisan Policy Center, Washington DC

Bodansky D (2010) The Art and Craft of International Environmental Law. Harvard University Press, Cambridge MA.

CBD (2010) Biodiversity and Climate Change, Decision X/33 of the Conference of the Parties to the Convention on Biological Diversity, Doc. UNEP/CBD/COP/DEC/X/33

Downs GW, Rocke DM, Barsoom PN (1996) Is the Good News about Compliance Good News about Cooperation? Int'l Org 50: 379-406

Fleming, JR (2010) Fixing the Sky: The Checkered History of Weather and Climate Control. Columbia University Press, New York.

Gardiner SM (2010) Is 'Arming the Future' with Geoengineering Really the Lesser Risk? Some Doubts about the Ethics of Intentionally Manipulating the Climate System. In Gardiner SM, Caney S, Jamieson J, Shue H (eds) Climate Ethics. Oxford University Press, Oxford

General Accounting Office (2010) Climate Change: A Coordinated Strategy Could Focus Federal Geoengineering Research and Inform Governance Efforts. Washington DC

Goodell J (2010) How to Cool the Planet. Houghton Mifflin Harcourt, Boston

Hamilton C (2010) The Return of Dr. Strangelove: The Politics of Climate Engineering as a Response to Global Warming. Available at: http://www.clivehamilton.net.au/cms/media/documents/articles/dr_strangeloves_return.pdf

Horton JB (2011) Geoengineering and the Myth of Unilateralism: Pressures and Prospects for International Cooperation. Stanford J Law Sci Policy 4: 56-69

House of Commons, Science and Technology Committee (2010) The Regulation of Geoengineering. Stationery Office, London

IPCC (2007) Climate Change 2007: Mitigation of Climate Change: Summary for Policy-Makers. Cambridge University Press, Cambridge

IPCC (2011) Meeting Report: IPCC Expert Meeting on Geoengineering, Lima, Peru, 20-22 June 2011

Kintisch E (2010) Hack the Planet. John Wiley, Hoboken

Lane L (2010) Plan B: Climate Engineering to Cope with Global Warming. American Enterprise Institute, Washington DC

Lempert RJ, Prosnitz D (2011) Governing Geoengineering Research: A Political and Technical Vulnerability Analysis of Potential Near-Term Options. Rand, Santa Monica

Lin AC (2009) Geoengineering Governance. Issues Legal Scholarship 8(3). Available at: http://www.bepress.com/ils/vol8/iss3/art2

London Convention (2008) Resolution LC-LP.1 on the Regulation of Ocean Fertilization

NAS (2002) Abrupt Climate Change: Inevitable Surprises. National Academies Press, Washington DC

NAS (2010) America's Climate Choices: Advancing the Science of Climate Change. National Academies Press, Washington DC

NAS (2011) Climate Stabilization Targets: Emissions, Concentrations and Impacts over Decades to Millennia. National Academies Press, Washington DC.

Olivier, JGJ, Janssens-Maenhout G, Peters JAHW, Wilson J (2011) Long-Term Trend in Global CO2 Emissions - 2011 Report. Netherlands Environmental Assessment Agency

Rayner S, Heyward C, Kruger T, Pidgeon N, Redgwell C, Savulescu J (2012) The Oxford Principles (this volume)

Royal Society (2009) Geoengineering the Climate: Science, Governance and Uncertainty. Royal Society, London

Royal Society (2011) Solar Radiation Management: The Governance of Research. Royal Society, London

Shelton D (ed) (2000) Commitment and Compliance: The Role of Non-Binding Norms in the International Legal System. Oxford University Press, Oxford

Sokolov, AP, Stone PH, Forest CE et al (2009) Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters, J Clim 22: 5175-5204

Teller E, Hyde R, Ishikawa M et al (2003) Active Stabilization of Climate: Inexpensive, Low Risk, Near-Term Options for Preventing Global Warming and Ice Ages Via Solar Radiation Forcing. Lawrence Livermore National Library

Victor DG (2008) On the Regulation of Geoengineering. Oxford Rev Econ Policy 24: 322-326

Victor DG, Morgan MG, Apt J, Steinbruner J, Ricke K (2009) The Geoengineering Option. Foreign Affairs (March/April)

Victor DG, Raustiala K, Skolnikoff EB (1998) The Implementation and Effectiveness of International Environmental Commitments. MIT Press, Cambridge MA

Virgoe J (2009) International Governance of a Possible Geoengineering Intervention to Combat Climate Change. Clim Chang 95: 103-19