Geography Compass 9/4 (2015): 190–201, 10.1111/gec3.12195

Geoengineering: The Next Era of Geopolitics?

Simon Dalby*
Wilfrid Laurier University, Balsillie School of International Affairs

Abstract

While geopolitics used to be about the context of global politics, now in the Anthropocene, it has become a matter of remaking that context rather than taking it as a given. What kind of planet is being made for what kind of civilization is now an unavoidable question of the global economy, as is the related political question of contemporary globalization concerning who decides the future planetary configuration. The discussion of geoengineering proceeds apace as the limited success of climate mitigation focuses attention on what comes next. Thinking about how to govern geoengineering before major experiments are tried unilaterally might be the key to preventing future conflicts over such practical issues as what temperature the planet ought to be. Such questions are the key to the new geopolitics of the Anthropocene, a debate to which geography in general and political geography in particular could have much to contribute.

> "Efforts to anticipate or predict how the future of international relations might unfold must consider what a majority of climate scientists and security experts already know— that we are entering a world of greater unpredictability and uncertainty as a result of human-induced changes. While climactic changes will certainly affect individuals and communities differently, the sheer range and scale of the potential consequences of a changing climate demands attention in any serious effort to imagine the geopolitical future." (Hommel and Murphy 2013: 520)

Geopolitics and Technology

Geopolitics is about how the world is known and imagined, and since European explorers first started to extend the reach of modern states, how it is understood as a whole to be divided up, assigned to supposedly sovereign rulers, and simultaneously incorporated into the growing global economy (Agnew 2003). American Cold War Culture shaped geopolitics profoundly (Farish 2010). How space is to be known, surveyed, dominated, and ruled has been an increasingly technical series of practices, of cartography, satellite surveillance, and the collection of vast amounts of information on people and economics as well as military matters. All this was tied into the rise of aviation, the first rockets capable of reaching earth orbit, and the horrors of nuclear weapons, radiation, and global atmospheric fallout.

New technological vistas for geopolitical conflict opened up as the technologies of surveillance expanded in the early Cold War years. The international geophysical year (1957/58) began a global monitoring of some key parameters of the earth system, only most obviously the levels of carbon dioxide in the atmosphere. Discussions of weather modification as a weapon of war were part of the Cold War rise of meteorology as a global science (Edwards 2010), and on a smaller scale, China continues to use cloud seeding techniques to adjust weather patterns. Matters of orbital space were an integral part of this conception with

Sputnik, the symbolic threat that galvanized the American NASA in the space "race." The world became the whole earth, a matter that apparently had to be secured as American policy (Deudney 1983). In the later years of the 1980s, these things connected up with nuclear war anxieties as discussions of nuclear winter and ozone depletion made it clear that the earth was vulnerable to human actions in ways that made the planet itself a material part of geopolitics.

Climate science has long been part of the geophysical knowledge base in military matters and technogeopolitics, but now, there is a new twist to this tale in plans to try to deliberately change planetary temperatures by "geoengineering." Technical discussions of how to engineer the climate and how hot the planet should get directly feed into political questions of what future the present generation is making for humanity (Yusoff 2013). Geopolitics is now about geological politics (Clark 2013). This suggests that geopolitics is about much more than the two dimensional map of world politics; it is about three dimensional, "vertical" geopolitics and a much more comprehensive appreciation of the materiality of the earth in global politics (Elden 2013). This requires thinking about the "geo-metrics," the key geophysical attributes of the planet such as levels of greenhouse gases in the atmosphere as an integral part of geopolitics (Dalby 2013). Economic activities are changing the global atmospheric composition, species mixes and such things as the acidity of the oceans for the future, matters that will shape the future context for global politics quite profoundly (Dalby 2014a).

The levels of greenhouse gases in the atmosphere are rising rapidly with little sign that they will be reduced soon, so discussions about deliberately "geoengineering" the climate are emerging in a serious conversation about attempting to shape new artificial climate configurations for the future (Keith 2013). Political geographers have not yet addressed this topic in much detail; this paper suggests that they should. To make this case, the paper first offers some brief comments about climate geopolitics, then summarizes some recent controversies over geoengineering experiments, and provides a brief overview of the techniques being discussed as part of geoengineering. Some of these are effectively existing climate mitigation measures already enmeshed in the global political economy, but they all require serious consideration in terms of how, given its potentially disruptive consequences, geoengineering might be governed. Finally, the paper reflects on what geoengineering and debates about how to govern it mean for the new discussions of material geopolitics in the Anthropocene.

Climate Geopolitics

Given the failures to reorganize the global economy on sustainable lines over the last few decades, geopolitics is now also part of the discussion of geoengineering and what techniques for adjusting the planetary temperature might be, ought to be, or should not be used, in the coming decades. While most policy makers and academics concerned with climate change policies shun the thought of intentionally manipulating the earth's climate, and do so for many good reasons, the debate about how to do so and who might govern or control such attempts has gathered pace (Kintisch 2010; Parkinson 2010). Clearly making provision for more extreme events in particular and ramping up the climate adaptation agendas more generally are now getting higher priority because the carbon dioxide concentration in the atmosphere continues to rise relentlessly.

Scenarios for a much warmer world with dramatic disruptions to existing climate patterns are becoming much more common (Anderson and Bows 2011). World Bank sponsored studies are warning that a much warmer world is a prospect that has to be avoided given the disruptions to natural and human systems that would be involved (Potsdam Institute 2012). But so far attempts to negotiate international agreements to deal with rising carbon dioxide in particular show few signs that they can produce agreements that will quickly prevent the anticipated disruptions. The question becomes "what then?" Given the failure of other modes of climate change governance to effectively curtail the growth of greenhouse gases in the atmosphere, the answer now frequently given is that artificial attempts to control planetary temperature by climate or "geo" engineering should be attempted (Luke 2010).

These discussions are now part of the policy deliberations around climate change, and as such, they are an important new part of geopolitics and worthy of serious attention by political geographers. This paper suggests that it is time to engage these discussions much more deeply, because to use Agnew's (2003) terms, how the world is known, divided up, and incorporated into the global economy is now also about how its future configuration is being decided. It is so because technical change and economic capacity are the key matters of geopolitics, ones that increasingly suggest the need to consider the planet as a limited entity, one in which geopolitical ambition has to be bounded by at least some restraints to prevent nuclear and other catastrophes (Deudney 2007).

Climate engineering or geoengineering (the terms are often used interchangeably) usually refers to artificial and deliberate attempts to manipulate a key facet of the earth's climate system. Questions of who should decide if and when these things might be tested, never mind actually deployed in efforts to deal with climate change disruptions, are controversial (Humphreys 2011). There is no apparently appropriate international governance regime, and neither the United Nations Environment Program nor the United Nations Framework Convention on Climate Change (UNFCCC) has the appropriate governance structure or agencies to undertake the task. Extensive technical concerns about geoengineering have been raised under the auspices of the Convention on Biological Diversity given the large uncertainties involved in any of these experiments (Secretariat of the Convention on Biological Diversity 2012). In particular, this mechanism has been used in attempts to ban ocean iron fertilization experiments, ones designed to cause plankton blooms in the hopes of sequestering carbon (Abate 2013).

Climate Experiments

These issues have been under discussion for some time, but they came to a head in October 2012 when media reports of an ocean iron seeding experiment off the West Coast of Canada earlier that year suggested that this was an unauthorized private experiment. The matter wasn't that simple, but the point that independent entrepreneurs could undertake such things without international oversight got attention (Tollefson 2012). While the fertilization of the ocean may or may not have caused a plankton bloom and it wasn't clear who was actually measuring what results, the lack of clarity about jurisdiction, coupled with the fact that this was a privately funded corporate initiative with plans to raise money through the sale of carbon credits, perhaps with the blessing of the local native population on Haida Gwai (Queen Charlotte Islands) or perhaps not, raised numerous practical questions of the politics and ethics of such experiments. Earlier in 2012, a British University project on the Stratospheric Particle Injection for Climate Engineering (SPICE) field experiment was canceled, in part because of confusion over patent applications and also because of concerns over the lack of transparent oversight of this experiment. Among the questions raised was one concerning who might own the technology should the field experiments with a small tethered balloon be upscaled to an operational attempt to inject sulfate aerosols into the atmosphere (Cressy 2012).

These two episodes highlight the simple fact that geoengineering is now actively being considered and is being bankrolled in part by corporate interests, not just government science programs. This is now combined with the growing alarm in global policy making circles that the current trajectory of climate change is toward the upper end of the scenarios that have been predicted the rate of global climate change (Potsdam Institute 2012). In these circumstances, it should come as no surprise that attempts to artificially adjust the planet's climate are getting serious attention from political and business elites anxious to maintain a relatively stable planetary system. In the United States, a bipartisan plan to comprehensively research geoengineering options has been published (Bipartisan Committee 2011). While there is a widespread consensus that geoengineering technologies should only be deployed as a last resort, given the present environmental trajectories, it is clear, as the recent popular summary of climate science by the National Academy of Science and the Royal Society (2014) emphasizes, that these matters need serious attention and soon.

Most discussions of geoengineering draw a distinction between two modes of addressing climate change (Royal Society 2009). First are measures of "Solar Radiation Management" (SRM), designed to reduce the level of insolation on the earth's surface and hence reduce the temperature and ease climate change accordingly. Second are measures of "Carbon Dioxide Removal" (CDR), to reduce the carbon dioxide levels in the atmosphere, dealing directly with the gas that matters most in determining the long-term temperature of the planet. SRM is a fairly obvious engineering in the sense of intentional attempts to directly change atmospheric conditions using technological means even if it is not in the sense of professional engineers using their skills to manipulate a well-understood technical system. CDR merges into matters more commonly talked about in terms of climate change mitigation such as afforestation and land use management to facilitate carbon storage. Nonetheless, the terminology is neither consistent nor precise. What is clear is that global failures to shape the global economy in ways that effectively maintain a stable climate are giving rise to discussions of SRM as an emergency measure to manage climate change (Luke 2010).

Recently, the Intergovernmental Panel on Climate Change (IPCC) discussed geoengineering in its fifth assessment report in enough detail to generate some policy implications. The summary for policy makers from the first working group explicitly stated that there was limited evidence concerning how much carbon might be removed from the atmosphere, and clearly, it warned that should SRM techniques be attempted and then terminated, the possibilities of rapid rise in global temperature were a substantial risk (IPCC 2013, 29). One key question that arises from this is whether geoengineering itself might in fact constitute the "dangerous anthropogenic interference with the climate system" that the UNFCCC was established to prevent.

Solar Radiation Management

SRM is about deliberate attempts to modify the climate system by directly intervening to adjust the temperature of the global system. Numerous technical possibilities are being discussed (Vaughan and Lenton 2011). Science fiction scenarios are numerous. Global parasols or sun-shields, large mirrors in the sky reflecting sunlight back into space and so on are obvious modes of lowering the intensity of the sun. Orbiting mirrors would need to be very large to be of much use given the sheer size of the surface of the earth. Such physical structures would involve huge amounts of material being lifted off the surface of the earth, and proposals for these devices far exceed the abilities of space programs to loft such things into orbit. Hence, most practical discussions of geoengineering are focused on doing things on earth, or at least in the atmosphere.

The overall goal of SRM is usually to keep the global climate system within the bounds of the Holocene range of temperature, the conditions that humanity is used to and crucially the conditions within which the global agricultural system functions. The most obvious atmospheric technologies for SRM include injecting sulfate aerosols into the high atmosphere effectively artificially mimicking volcanoes that periodically cool the planet (Hulme 2013).

Calculating how much sulfate or other aerosol is needed to make a difference suggests that this is a feasible possibility using a modest fleet of aircraft flying in the stratosphere. It has the advantage of being reversible; should a major volcanic eruption happen, the aircraft can immediately cease operation, and the artificial aerosols will gradually fall back to earth. The problems with acid precipitation and the difficulty of calibrating how much aerosol is needed where and when in the atmosphere are not trivial. But given the present circumstances, advocates of climate engineering argue that small scale experiments are essential to begin to investigate the physical processes involved in some detail so informed inferences can be made about the likely consequences of deploying these technologies on the large scale (Keith 2013).

Another popular suggestion is albedo modification, to increase the reflectivity of the earth's surface by such expedients as using lots of white paint on new construction to simultaneously cool buildings in summer and reflect more sunlight. Increasing cloud cover by artificially producing clouds, or seeding existing ones to extend their size or brightness and hence reflectivity, is also actively being considered, in particular in the Arctic where the world is heating most rapidly. However, given the relatively low level of technology involved in such things as artificial cloud making by spraying sea water into the lower atmosphere from ships, such projects are feasible engineering possibilities in the immediate future, even if it is entirely unclear how effective they might be or what unforeseen consequences might eventuate. It is the latter point that underlies much of the opposition to geoengineering (Hamilton 2013) and which raises the key questions about how to govern geoengineering experiments in the short term. The other key criticism of SRM is that it doesn't deal with ocean acidification caused by elevated levels of carbon dioxide being absorbed by seawater. In the words of Claire Parkinson's (2010) book title, such complexities should make one very wary of "the big fix"!

Carbon Dioxide Removal

If not SRM, then the alternative would seem to be actively trying to reduce the atmospheric concentration of carbon dioxide (Meadowcroft 2013). Under the rubric of carbon capture and storage, various technical projects to remove carbon dioxide from the atmosphere have been suggested, and while optimism abounds concerning the potential of these technologies, little has been proven effective as yet, much less been deployed at the industrial scale. Attaching devices that remove carbon dioxide from the stacks of coal-fired electrical power stations would be especially useful, but the cost and engineering matters have yet to be dealt with effectively to facilitate the large-scale deployment of these methods. The advantage of such technologies, always assuming that they can be made to work over the long term, is that they directly tackle the problem of carbon dioxide emissions at source.

Other less direct methods include those mentioned above related to ocean seeding or fertilization, whereby plankton blooms are promoted on the theory that these will absorb carbon dioxide and when the plankton die, the carbon that they have absorbed will fall to the ocean floor and be removed from circulation (Abate 2013). Given that the ocean absorbs a substantial amount of carbon from the atmosphere at present, but as concentrations rise may do so to a lesser degree, and that the carbon is acidifying the ocean and disrupting marine life as a result, ocean seeding should have multiple benefits. But given the numerous unknowns about the ecological effects of ocean seeding on other marine life forms, these proposals too have been controversial as the arguments over the seeding experiment off the West Coast of Canada in 2012 made abundantly clear.

On land, the possibilities of biochar or sequestering carbon in the form of charcoal have been discussed recently with various measures to facilitate this being tried. But what is complicated here is the simple facts that farming practices, which charcoal production is embedded in, are not just about carbon removal from the atmosphere but also complicated matters of food production and rural land use that defy easy use as carbon sinks, whatever the grand schemes of geoengineering might hope (Leach et al. 2012). Wetlands likewise are an obvious alternative method of extracting carbon from the atmosphere, but over the last century, draining wetlands to provide agricultural land has been the priority, not facilitating their expansion. Bogs, the ideal ecosystems for sequestering carbon given that dead vegetation is preserved rather than decaying with the resultant carbon dioxide release, were in many cases in the twentieth century simply been turned into fuel. While replacing the bogs with short rotation forestry might provide something close to a "carbon neutral" fuel source in future, at least this bogs' carbon removal function is a thing of the past.

Beyond this reforestation on the large scale might offer considerable potential for carbon sinks, and forestry plantations have been part of the carbon offset industry for the last few years. Such mitigation measures are part of the larger political economy of climate adaptation too, where attempts by national governments and major corporations to gain access to the land in Africa in particular are part of the larger processes of "land-grabbing" that is disrupting rural political economies, tying agricultural change once again into matters of geopolitics (Dunlap and Fairhead 2014). But in considering reforestation on the large scale, the definitional issue of what is geoengineering rather than a climate mitigation measure becomes complicated. Land use issues are the key to mitigation, both because of the emissions from agriculture and the large emissions from automobile dependent suburbs and because of the potential for revegetating forests to reduce carbon levels in at least the short term.

But is this really geoengineering? Perhaps, it might be better understood as modes of ecologically friendly economic development. At best, these might be considered a "softer" version of geoengineering (Olson 2012). Viewed in these terms, many land use changes might be discussed in terms of geoengineering too, raising definitional matters concerning what is deliberate attempt to change the climate or merely a routine matter of political economy, which has, of course, climate change consequences. It is, as this paper emphasizes, the failure of routine political economy to curtail carbon emissions that has triggered the rapidly growing geoengineering discussion in the first place.

Political Economy and Climate Change

Reducing emissions is essential if the planet is to remain in something approximating the climate regime that civilizations have so far known. Carbon capture and storage to deal with remaining emissions also help indirectly with the other major issue related to CO2, that of the acidification of the oceans. Further measures focusing on the reduction of black carbon, methane, and other greenhouse gas reduction mechanisms are also important, especially as short-term expedients to ease global warming, but none of these measures will solve the long-term problem of rising carbon levels in the atmosphere (Guivarch and Hallegatte 2013). Once the argument engages the discussions of soft geoengineering or CDR, it merges with matters of political economy and development strategies directly. The global economy then becomes the issue, and CDR becomes part of the larger discussion of sustainability and, to use the language from the United Nations GEO 5 report in 2012, thinking about "environment for the future we want."

Given the scale of economic activity that transformed so many things in the twentieth century, traditional ideas of protecting environments are no longer the appropriate way to plan the next stage of the Anthropocene, one that requires human stewardship if we are to move toward a sustainable earth (Steffen et al 2011). The point is not that "environmental" matters are unimportant but to recognize that the scale of human activity has long had major effects on the rest of the earth system and that what humans make is the key to the future; climate change is a production problem not a traditional "environmental" protection problem. The assumption of a separate nature out there to be preserved is no longer the appropriate geopolitical framing for serious climate discussions (Dalby 2014b). Concerted efforts to reduce carbon dioxide emissions and shape landscapes and cities to better tolerate more extreme events, an explicit attempt to undertake planetary stewardship, should make a much safer world for future generations.

Given that humanity is quite literally shaping the future configuration of the biosphere and that the capitalist order of the present has so far proved incapable of arranging matters so that human circumstances are maintained in something approximating Holocene conditions, very big political questions are now in need of attention. But clearly attempting to squeeze them into the geopolitical straight jackets of the past where great power rivalry is the taken for granted context will not produce sensible innovations precisely because that context is a thing of the past (Hommel and Murphy 2013). The power of the fossil fuel industry to shape the rules of markets makes it highly unlikely that supposedly free markets will deliver a more sustainable future (Mitchell 2011). Given the interconnectedness of climate matters as well as the globalization of the economy, these things require multilateral institutions and economic innovations simultaneously. But precisely because the global political economy has failed to generate such things, the assumption that emergency efforts at geoengineering will be tried in their absence underscores both the urgency of addressing these experiments and the need to try to put some international governance structure into place.

Governing Geoengineering

The question of how to govern international research efforts on geoengineering and solar radiation management in particular is now a pressing issue (Burns and Strauss 2013; Galaz 2012), highlighted by the controversies over ocean seeding and SPICE in 2012. None of the standard environmental governance mechanisms, the UNFCCC, the London Ocean Dumping convention, or the Convention on Biological Diversity (CBD), obviously fit well. Notwithstanding this, the CBD did act to attempt to ban geoengineering experiments that might affect biodiversity at its 2010 annual meeting. At least so far, there has not been any reason to invoke the 1970s agreements against using environmental modification as a weapon of war, not least because they only deal with hostile environmental actions, not general matters of environmental change. Nonetheless, forestalling such invocations would seem to be prudent politics given the rapidly changing climate configuration that we can expect in coming decades if drastic action isn't taken soon (Anderson and Bows 2011).

The key point in all this is the recognition of the interconnectedness of the biosphere; international cooperation is simply essential because the potential for misunderstandings is huge if transparency isn't obvious (Solar Radiation Management Governance Initiative 2011). The implicit geography is one of a common context, not one amenable to regional or unilateral actions, although attempts to slow the warming in the Arctic in particular may strain the relations in the region, especially among those anxious to exploit the resources there made accessible by the disappearance of sea ice. All of which makes thinking about how to govern such matters in a way that anticipates possible future difficulties urgent. One preliminary attempt to focus thinking on these matters is the Oxford principles drafted by the Oxford University program on geoengineering. There are five principles expressed in general terms that encapsulate many of the key themes that need attention (Rayner et al. 2013). While they have been adopted in Britain and discussed elsewhere, they are as yet guidelines rather than an official arrangement.

The need for such guidelines lies in the potential geopolitical dangers of unilateral action by a state or corporate enterprise, especially so either if unilateral action by one state has direct impacts on another state or if political leaders suspect that secret work on geoengineering is being undertaken by a state entity in a way that may have negative ecological consequences for their state. Given the obvious transboundary repercussions of any experiment, especially one that has unforeseen negative and perhaps irreversible consequences, the potential for conflict could be very considerable (Urpelainen 2012). But on the other hand, precisely because of the interconnectedness of ecological phenomena, it is clear that uncoordinated efforts by individual states are likely to be much less effective than coordinated attempts. For instance, attempts at Arctic cooling by aerosol injection to enhance precipitation and hence snow generated albedo reduction might be counteracted by injections elsewhere that reduce vapor transport to polar regions (Horton 2013), and hence, there is a large technical incentive for states considering geoengineering to cooperate.

Whether the political incentives in a geopolitically divided world will line up with the technical matters is much less clear. While China has a history of smaller scale weather modification efforts, so far, there is little indication that serious thought has been given there to scaling these up to attempt unilateral SRM (Edney and Symons 2014). The simple fact that researchers elsewhere are working on possible technologies and worrying about such things as whether SRM might disrupt Asian monsoons, with all the consequences that this might have on food production in India and China if they were tried, makes clear that getting agreements on the "rules of the road" for experimenting or deploying such technologies in advance is crucial, whether under the UNFCCC or some other arrangement.

First in the Oxford principles is the obvious point that geoengineering needs to be regulated as a public good so that timely regulation of any private initiatives is in place, whether at national or international levels, so that needed technologies are available if necessary. Complicated matters of private corporations, patents, and property are unavoidable in the present global political economy, but the necessity of public transparent oversight is the key. Given the potential for international misunderstanding should militaries work seriously on these themes, transparency is especially important as a confidence building measure.

Public participation in any decision concerning geoengineering requires some sort of informed consent on the part of those affected by the specific technique; this is the essence of the second principle. This is obviously important but given the complexity of global ecological matters and the possibility of unanticipated ecological teleconnections, a very difficult matter to address effectively. All of which is much more difficult for solar radiation management rather than carbon dioxide removal, given that there is no effective "democratic" oversight in international affairs. Clearly, participation by civil society in these deliberations would help, but a democratic deficit persists on such matters where technical decisions have profound effects (Szerszynski et al. 2013). How to address this is one of the challenges of global governance; it is part of the new geological politics of our times that geography as a discipline should have much to contribute to in both the technical and political dimensions of geoengineering.

The third principle emphasizes the importance of complete transparency of research plans and the publication of scientific results in ways that ensure that all information including negative results be a matter of public record. This will allow for public assurance that the process has integrity, and hence will allow public confidence in what is going on. Common "rules of the road" would have advantages in that it's clear on what is being done and who is monitoring the experiments. In doing so, the implicit geopolitical contextualization is not the traditional one of unconstrained competing rival powers but one of increasingly enmeshed powers forced to consider cooperation in the face of a rapidly change geographical context. Related to this is the fourth principle that emphasizes independent assessments of impacts, a tricky matter where transboundary effects are likely, but a matter than cannot be ignored. This obviously requires assessments by international scientific bodies looking at the implications of path dependencies with particular technologies.

The fifth principle may in some ways be the most important. It stipulates that "robust governance structures" must be in place prior to decisions being taken. If possible, existing institutions and rules should guide the decisions. Given the novelty, scale, and seriousness of the issues, this may be difficult to do, but the urgency of dealing with atmospheric levels of carbon dioxide rising above 400 ppmv is increasingly compelling (Humphreys 2011). Nonetheless, the necessity of putting institutions in place prior to deploying geoengineering technologies so that the rules of the game are established in advance is clear (Solar Radiation Management Governance Initiative 2011). This is especially important given the wide range of uncertainties in the whole process, one that hasn't been clarified very much so far by the various attempts to do comprehensive appraisals of geoengineering research (Bellamy et al. 2013).

One point that has become clear in all this is that traditional notions of political sovereignty and models of territorial states protecting fixed boundaries aren't useful modes of thinking about this problem. Just as with other matters where notions of sovereign territory don't provide a useful way of thinking or acting if the complexity and interconnections of nature are taken seriously (Smith 2011), in the case of geoengineering, territorial strategies are not the practical modes for considering SRM with all its potential global effects. The case for CDR is different in that land use changes, such things as attempts to cool cities by planting trees or simply painting roofs white to reflect sunlight, are mitigation measures that do affect the climate and can be decided locally. Given these interconnections, one of the key conclusions from the current project on "Integrated Assessment of Geoengineering Proposals" (http://www.iagp.ac.uk/) is that geoengineering has to be considered as part of the mitigation and adaptation policy discussion, not separate from it.

Geopolitics in the Anthropocene

None of the Oxford principles can effectively grapple with the larger ethical questions concerning geoengineering (Preston 2011). There is no right answer as to how hot the planet should get, although precautionary principles would suggest that keeping it close to twentieth century levels, ones for which substantial parts of human infrastructure was constructed, is the obvious reply. As Burns (2013) notes keeping options open for future generations is a key ethical point, encoded in arguments about sustainability, one facilitated by maintaining the planet in something close to present conditions. However, the discussion of the Anthropocene makes clear that there is now no given nature that can literally ground ethical concerns (Castree 2014a,2014b,2014c). The point is emphasized in the climate change campaign "350.org" that incorporates a political demand for a specific level of global atmospheric carbon dioxide right in the name of the organization.

Many of the critiques of geoengineering proposals, summarized elegantly and persuasively by Clive Hamilton (2013), object to further technological interventions into natural systems to supposedly fix the problems caused by prior uses of large-scale engineering. This "Promethean" understanding of geoengineering, as more attempts to force an external recalcitrant system to do our bidding, nonetheless falters in the face of the realization of the scale of transformations already wrought by humanity. This crucial recontextualisation, an updating of the geography to focus on our present circumstances, suggests that there is no external entity to bring engineering to bear on. Promethean formulations, epitomized by solar radiation management techniques, just suggest an extension of artificial efforts to shape the terrestrial environment to maintain the existing global economy. Business as usual, quite literally!

While in Hamilton's (2013) terms, the "Soterian" alternative of making much less ecologically disruptive modes of living widespread, facilitating ecological adaptation and focusing on CDR, rather than trying to use something akin to brute force to ameliorate climate difficulties, makes more sense; it simply may not be possible to do this in the present global political economy in time to prevent dramatic climate disruptions. The proliferation of market place economies that are the key to the processes of globalization now constitutes the ecological transformation that is the Anthropocene (Dalby 2014a). Understanding them as such suggests that rapid reform of the global political economy is essential to produce less disruptive modes of production in coming decades (Stiglitz and Kaldor 2013). But if this isn't forthcoming, the arguments for SRM will probably gain force among political elites anxious to maintain control over social forces in an increasingly volatile world and willing to use apocalyptic arguments, force, and sophisticated technology to do so (Swyngedouw 2010).

Rather than face such a prospect, new institutions and practices are starting to emerge to try to bridge what Victor Galaz (2014) calls the "Anthropocene Gap" between technology, politics, and environmental governance. These include corporate attempts to think about supply chains, urban regeneration efforts using green technologies, and a large number of innovative political mechanisms that escape any neat categorization in terms of nation states (Bulkeley et al. 2014). There is also a growing social protest movement on climate matters linking local attempts to stop destructive mining and petroleum extraction with fossil fuel divestment movements and attempts in various places to retake municipal control over essential utilities and energy systems (Klein 2014). Climate geopolitics still matters in terms of states and the UNFCCC arrangements, but attempted governance of climate is now about a much broader set of social initiatives, many of them directly related to technological innovations.

While the Cold War technological innovations of long-range rockets, satellite surveillance, and nuclear weapons changed geopolitics dramatically, the routine mundane operations of the fossil-fueled economy are now changing it again in ways that make traditional notions of territorial sovereignty even more dubious as a way to consider governance and politics. Understanding geopolitics as much more than a flat map of world politics (Elden 2013), and instead in terms of geological transformation caused by human action (Yusoff 2013), is the key to contextualizing geoengineering appropriately and clarifying the policy options for both Prometheans and Soterians. Investigating the contextual premises in this discussion and their political implications is now a new but important scholarly task for all political geographers interested in how humanity will shape the next stage of the Anthropocene.

Short Biography

Professor Simon Dalby, formerly at Carleton University, is now CIGI Chair in the Political Economy of Climate Change at the Balsillie School of International Affairs and Professor of Geography and Environmental Studies at Wilfrid Laurier University, Waterloo, Ontario. He is the author of *Creating the Second Cold War* (Pinter 1990), *Environmental Security* (University of Minnesota Press, 2002) and *Security and Environmental Change* (Polity, 2009).

Note

* Correspondence address: Simon Dalby, Balsillie School of International Affairs, Wilfrid Laurier University, 67 Erb Street West, Waterloo, ON N2L 6C2 Canada. E-mail: sdalby@gmail.com

References

Abate, R. S.(2013). Ocean iron fertilization: science, law and uncertainty in burns. In: Burns W. C. G. and Strauss, A. L. (eds) *Climate change engineering*. Cambridge University Press: Cambridge, pp.221–241.

Agnew, J.(2003). *Geopolitics: revisioning world politics*. Routledge: New York.

Anderson, K. and Bows, A.(2011). Beyond dangerous climate change: emission scenarios for a new world. *Philosophical Transactions of the Royal Society A* 369, pp. 20–44.

Bellamy, R., Chilvers, J., Vaughan, N. E. and Lenton, T. M.(2013). 'Opening up' geoengineering appraisal: multi-criteria mapping of options for tackling climate change. *Global Environmental Change* 23(5), pp. 926–937.

Bipartisan Policy Center(2011). *Geoengineering: a national strategic plan for research on the potential effectiveness, feasibility, and consequences of climate remediation technologies*. Bipartisan Policy Center: Washington.

Bulkeley, H., Andonova, L. B., Betsill, M. M., Compagnon, D., Hale, T., Hoffmann, M. J., Newell, P., Paterson, M., Roger, C. and Vandeveer, S. D.(2014). *Transnational climate change governance*. Cambridge University Press: Cambridge.

Burns, W. C. G.(2013). Climate geoengineering: solar radiation management and its implications for intergenerational equity in burns. In: Burns, W. C. G. and Strauss, A. L. (eds) *Climate change engineering*. Cambridge University Press: Cambridge, pp.200–220.

Burns, W. C. G. and Strauss, A. L. (Eds)(2013). *Climate change geoengineering: philosophical perspectives, legal issues and governance frameworks*. Cambridge University Press: Cambridge.

Castree, N.(2014a). The Anthropocene and geography I: the back story. *Geography Compass* 8(7), pp. 436–449.

Castree, N.(2014b). The Anthropocene and geography II: current contributions. *Geography Compass* 8(7), pp. 450–463.

Castree, N.(2014c). The Anthropocene and geography III: future directions. *Geography Compass* 8(7), pp. 464–476.

Clark, N.(2013). Geoengineering and geologic politics. *Environment and Planning A* 45(12), pp. 2825–2832.

Cressy, D.(2012). Geoengineering experiment cancelled amid patent Row. *Nature* 15, doi: 10.1038/nature.2012.10645.

Dalby, S.(2013). The geopolitics of climate change. *Political Geography* 37, pp. 37–48.

Dalby, S.(2014a). Environmental geopolitics in the twenty first century. *Alternatives: Local, Global, Political* 39(1), pp. 1–14.

Dalby, S.(2014b). Rethinking geopolitics: climate security in the Anthropocene. *Global Policy* 5(1), pp. 1–9.

Deudney, D. (1983). *Whole earth security: a geopolitics of peace*. Washington: Worldwatch Institute, Worldwatch Paper 55.

Deudney, D.(2007). *Bounding power: republican security theory from the polis to the global village*. Princeton University Press: Princeton.

Dunlap, A. and Fairhead, J.(2014). The militarisation and marketisation of nature: an alternative lens to 'climate-conflict'. *Geopolitics* 19(4), pp. 937–961.

Edney, K. and Symons, J.(2014). China and the blunt temptations of geo-engineering: the role of solar radiation management in China's strategic response to climate change. *The Pacific Review* 27(3), pp. 307–332.

Edwards, P. N.(2010). *A vast machine: computer models, climate data, and the politics of global warming*. MIT Press: Cambridge MA.

Elden, S.(2013). Secure the volume: vertical geopolitics and the depth of power. *Political Geography* 34, pp. 35–51.

Farish, M.(2010). *The contours of the American Cold War*. University of innesota Press: Minneapolis.

Galaz, V.(2012). Geo-engineering, governance, and social-ecological systems: critical issues and joint research needs. *Ecology and Society* 17(1), pp. 24.

Galaz, V.(2014). *Global environmental governance, technology and politics: the Anthropocene Gap*. Edward Elgar: Cheltenham.

Guivarch, C. and Hallegatte, S.(2013). 2C or not 2C? *Global Environmental Change* 23, pp. 179–192.

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

Hommel, D. and Murphy, A. B.(2013). Rethinking geopolitics in an era of climate change. *GeoJournal* 78, pp. 507–524.

Horton, J. B.(2013). Geoengineering and the myth of unilateralism: pressures and prospects for international cooperation. In: Burns, W. C. G. and Strauss, A. L. (eds) *Climate change engineering*. Cambridge University Press: Cambridge, pp.168–181.

Hulme, M.(2013). Climate change: climate engineering through stratospheric aerosol injection. *Progress in Physical Geography* 36(5), pp. 694–705.

Humphreys, D.(2011). Smoke and mirrors: some reflections on the science and politics of geoengineering. *Journal of Environment and Development* 20(2), pp. 99–120.

IPCC(2013). Summary for policymakers. In: *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 University Press: Cambridge.

Keith, D.(2013). *A case for climate engineering*. MIT Press: Cambridge MA.

Kintisch, E.(2010). *Hack the planet: science's best hope – or worst nightmare – for averting climate catastrophe*. Wiley-Blackwell: Hoboken, NJ.

Klein, N.(2014). *This changes everything: capitalism vs. the climate*. Knopf: Toronto.

Leach, M., Fairhead, J. and Fraser, J.(2012). Green grabs and biochar: revaluing African soils and farming in the new carbon economy. *The Journal of Peasant Studies* 39(2), pp. 285–307.

Luke, T.(2010). Geoengineering as global climate change policy. *Critical Policy Studies* 4(2), pp. 111–126.

Meadowcroft, J.(2013). Exploring negative territory: carbon dioxide removal and climate policy initiatives. *Climatic Change* 118, pp. 137–149.

Mitchell, T.(2011). *Carbon democracy: political power in the age of oil*. Verso: London.

National Academy of Sciences and Royal Society(2014). *Climate Change: Evidence and Causes*. National Academy of Sciences and Royal Society: Washington and London.

Olson R. (2012). Soft geoengineering: a gentler approach to addressing climate change. *Environment September/October*, pp. 29–39.
Parkinson, C.(2010). *Coming climate crisis? Consider the past, beware the big fix*. Rowman and Littlefield: Lanham.
Potsdam Institute for Climate Impact Research and Climate Analytics(2012). *Turn down the heat: why a 4oC warmer world must be avoided*. World Bank: Washington.
Preston, C. J.(2011). Rethinking the unthinkable: environmental ethics and the presumptive case against geoengineering. *Environmental Values* 20(4), pp. 457–479.
Rayner, S., et al.(2013). The Oxford Principles. *Climatic Change* 121, pp. 499–512.
Royal Society(2009). *Geoengineering, science, governance and uncertainty*. Royal Society: London.
Smith, P. M.(2011). *Against Ecological Sovereignty: Ethics, Politics, and Saving the Natural World University*. Minnesota Press: Minneapolis.
Solar Radiation Management Governance Initiative (2011). Solar radiation management: The governance of research. http://www.srmgi.org/report/ Accessed 3 April 2014.
Steffen, W., et al.(2011). The Anthropocene: from global change to planetary stewardship. *Ambio* 40, pp. 739–761.
Stiglitz, J. and Kaldor, M. (Eds)(2013). *The quest for security: protection without protectionism and the challenge of global governance*. Columbia University Press: New York.
Swyngedouw, E.(2010). Apocalypse forever? Post-political populism and the spectre of climate change. *Theory, Culture & Society* 27(2-3), pp. 213–232.
Szerszynski, B., Kearnes, M., Macnaghten, P., Owen, R. and Stilgoe, J.(2013). Why solar radiation management, geoengineering and democracy won't mix. *Environment and Planning A* 45, pp. 2809–2816.
Tollefson, J. (2012). Ocean fertilization project off Canada sparks furore *Nature* 490 October 25.
United Nations Environment Program(2012). *GEO5 global environment outlook: environment for the future we want*. UNEP: New York.
Urpelainen, J.(2012). Geoengineering and global warming: a strategic analysis. *International Environmental Affairs* 12(4), pp. 375–389.
Vaughan, N. E. and Lenton, T. M.(2011). A review of geoengineering proposals. *Climatic Change* 109(3/4), pp. 745–790.
Yusoff, K.(2013). The geoengine: geoengineering and the geopolitics of planetary modification. *Environment and Planning A* 45(12), pp. 2799–2808.