Geoengineering: A war on climate change?

Andrew Lockley

andrew.lockley@gmail.com

Abstract

Geoengineering, specifically Solar Radiation Management (SRM), has been proposed to effect rapid influence over the Earth's climate system in order to counteract Anthropogenic Global Warming. This poses near-term to long-term governance challenges, some of which are within the planning horizon of current political administrations. Previous discussions of governance of SRM (in both academic and general literature) have focused primarily on two scenarios: an isolated "Greenfinger" individual, or state, acting independently (perhaps in defiance of international opinion); versus more consensual, internationalist approaches. I argue that these models represent a very limited sub-set of plausible deployment scenarios. To generate a range of alternative models, I offer a short, relatively unstructured discussion of a range of different types of warfare – each with an analogous SRM deployment regime.

1. Introduction

Geoengineering can be divided into two broad categories: Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM) (Brovkin et al. 2009).

CDR techniques, otherwise known as GGR (Greenhouse Gas Removal), are significantly less controversial in the short to medium term than are SRM techniques. CDR options are relatively slow-acting, and are typically more expensive than SRM (Brovkin et al. 2009). Thus, issues of near-term temperature governance and control (i.e. of "who controls the thermostat") do not apply. The control issue is distinct from the more general environmental impacts of CDR, which may have cross-border implications in the same way that many other environmental issues do. For example, extensive tree-planting will necessarily affect regional hydrology. As this article is concerned with control controversy, I focus only on SRM. I therefore, unless otherwise specified, use the word "geoengineering" to refer only to SRM geoengineering. Furthermore, unless otherwise specified, Stratospheric Aerosol Injection (SAI) is my focus. As it is based on volcanic analogues, SAI is currently much better understood than other forms of SRM. Nevertheless, Marine Cloud Brightening could be a viable technology for many scenarios in what follows.

Solar radiation management is not a new idea (Budyko 1977). However, the failure of the world's governments to enact a functioning agreement to mitigate emissions and manage resulting climate change (Pachauri et al. 2014) has spurred new interest in the field, and its governance – in both general literature (e.g. *Economist* 2010) and academic discourse (Robock 2008). With a few exceptions (e.g., Bernstein et al. 2013), most proposed atmospheric SRM schemes are designed to substantially modify global climate. Unless stated otherwise, I assume throughout this article that the schemes under discussion are fundamentally global in nature. Note, however, that regionally focused geoengineering is indeed possible, and is discussed in various scenarios.

The word "governance" can be used in a variety of ways. One relevant definition is: "the use of institutions, structures of authority and even collaboration to allocate resources and coordinate or control activity in society or the economy" (Bell 2002). According to the Governance Analytical Framework (Hufty 2011), governance can be defined in broader terms. It refers to the "processes of interactions and decision-making among the actors involved in a collective problem, that lead to the creation, reinforcement or reproduction of social norms and institutions." In this article, I use a concept of governance based very loosely on this approach. By way of background, the World Bank has previously used other comparable definitions of governance (World Bank, 1991). Whilst both approaches may be regarded as legitimate, the reason for the application of a broader definition here is that it is necessary to consider both formal and informal governance mechanisms. The latter may have a critical influence on the process. Individuals, untraceable or unaccountable organisations, and religious groups, are relevant examples of influencers that may not be considered by narrower definitions.

Framing of SRM deployment scenarios has typically centered on two, essentially opposite, scenarios. The unilateral actor scenario is often discussed in climate geoengineering literature. This scenario contemplates deployment of a geoengineering approach by a wealthy individual who uses his money to fund a geoengineering project (Victor 2008). However, some commentators have also suggested that the intervention might be by a "rogue" state (Millard-Ball 2012) or superpower (Irfan 2013). Indeed, so common is the rogue framing that a neologism has been coined to describe it – the "Greenfinger" individual (Randerson 2008) – a wordplay on the James Bond character Goldfinger (Fleming 1959). The second, alternative, framing that is frequently discussed is that of a global consensus (Rayner et al. 2013) or international agreement (Ricke, Moreno-Cruz, and Caldeira 2013) facilitating establishment of a geoengineering governance framework.

Without dismissing these helpful framings, I suggest that there is a need to identify the full potential range of alternative scenarios under which geoengineering strategies might be deployed. Accordingly, it is appropriate to seek examples of alternative policies or events in an effort to explore applicable analogues for SRM deployment. One activity commonly conducted or considered by politicians is engagement in warfare. War has, of course, been discussed extensively in academia and in general literature, particularly the news media. The extensive library of available material makes it ideal for studying, in order to elicit potentially useful parallels and analogues.

I'll begin, then, with a brief general discussion of the relevance of the warfare analogue, and then introduce the historical governance of warfare. The approach includes a sequential discussion of diverse types of warfare (e.g. civil war) with an attempt to parallel each one with an analogous geoengineering scenario. In conclusion, I'll reflect further on the usefulness of the approach.

1.1 The warfare analogue

SRM geoengineering is technological and deliberate in nature, and has the potential for transboundary effects (Rayner et al. 2009). Accordingly, it may have features in common with warfare, with respect to

governance, regulation, and control, allowing a structured and productive comparison with the governance and conduct of war. In particular, I note the following comparable features:

1. Global effect – Most proposed SRM schemes are considered to have global impacts, in common with the use of nuclear weapons and other weapons of mass destruction (Martin 1982). SRM is anticipated to provide a benefit (at least to the deployer), but this may be uneven, with significant detriment to certain populations possible – even if such technologies yield a net global benefit (Ricke, Moreno-Cruz, and Caldeira 2013; Tilmes et al. 2013).

2. Civilian impact – Rado (2011) describes several regulated or prohibited types of military intervention likely to affect civilians. Comparably, SRM is expected to have wide-ranging effects on civilian populations. Mechanisms of action include changes to the hydrological cycle (Bala, Duffy, and Taylor 2008) and to the balance of direct and diffuse light, both of which may affect agricultural productivity (Pongratz et al. 2012).

3. Transboundary effect – In common with weapons of mass destruction, SRM is likely to have a strategic and uneven impact on countries (Ricke, Morgan, and Allen 2010). Even the smallest aerial schemes will tend to cause significant effects at city-region scale (Bernstein et al. 2013), which has potential for direct overspill – particularly in smaller countries and border areas. Transboundary effects can generally be expected from overspill or from teleconnections (Royal Society 2009; House of Commons 2010).

4. Long duration of action – Whilst the use of small arms is often lightly regulated (Small Arms Survey 2007) weapons and campaigns that operate on longer timescales or geographical areas are typically regulated higher up the military/political chain of command (e.g. the Geneva Protocol's consideration of chemical weapons). Geoengineering timescales and areas of effect are comparable to those of weapons of mass destruction (Brovkin et al. 2009; Cao and Caldeira 2010). Therefore, I note the potential to establish analogues to the regulation of these technologies.

1.2 Governance of warfare – a brief context

Warfare is often tightly constrained by legal instruments (e.g. treaties and customary international law) and informal restrictions (e.g. societal norms). In contemporary times, regulatory and governance structures are provided in a variety of ways. These include the international treaty framework that establishes rules for warfare: e.g. the Geneva Protocol (1925) and relevant provisions of the United Nations Charter. The parallels between warfare and geoengineering are not merely metaphorical: specific limitations on the use of geoengineering technologies in warfare arguably already exist (ENMOD 1977).

Whilst the governance of warfare may superficially appear to be regulated primarily by treaty, the reality is more subtle and complex, and many additional institutions and other factors play a role. These include domestic laws or democratic oversight (House of Lords Committee 2006) and the informal international supervision and prioritization of norms – as recently demonstrated by the "Red Line" over Syrian chemical attacks (Kessler 2013). Accordingly, there are significant limitations on the use of warfare in general, as regards its inception and conduct. The process of regulating warfare varies dramatically in time, space, and context. For example, air warfare has been considered in widely differing ways throughout its evolution (Gómez 1998). A specific example reflects changing attitudes: area bombing was accepted by both sides in World War II as a legitimate practice (Primoratz 2010), although it was not without contemporary dissent. By contrast, in contemporary times even the non-lethal targeting of civilians, such as by disabling power grids, is considered to be a war crime in some circumstances (Rado 2011). Likewise, geographical variances exist – with drone strikes of questionable legality (BBC news

2013b) tolerated in comparatively lawless and unstable theatres (Yemen, Pakistan) – but not for targets of a similar nature in New York or London. Context provides an important guide to acceptability, with the controversy over Pakistan's reaction to the killing of Osama bin Laden (Perlez and Rohde 2011) perhaps exacerbated by its location in an otherwise stable urban area, and by the domestic nature of the target.

In summary, this patchwork of formal and informal rules of war provides a useful parallel to considerations applicable to SRM governance.

2. Comparative analysis approach

Warfare is governed and controlled in a wide variety of ways, according to the extent and style of the conflict. Other factors influencing governance include the number of participants and their economic, technological, and social sophistication. Considered in the following sections are a broad range of styles of warfare, which I explore using two techniques. First, I seek to draw parallels between warfare and possible SRM deployment scenarios. Second, where applicable, I consider scenarios where SRM is part of the context for warfare.

I discuss the following classes of conflict: rogue state, technocratic intervener, coalition of the willing, superpower, proxy war, unidentifiable actor, terrorist, civil war, bilateral conflict, internecine conflict, and global ideological war. Many other subcategories or alternative patterns of conflict could be envisaged, and the demarcation between different styles is largely arbitrary, with significant overlap.

Such analogues are necessarily imperfect. However, the consideration of analogous conflicts is helpful in broadening the range of deployment scenarios debated in the literature (which does not currently include many of those scenarios which I discuss).

These scenarios merit a range of discussion lengths and types, and I do not employ a rigorous, formal approach – nor are the discussions necessarily consistent in length or style. Where applicable, I briefly discuss the political, social, and legal factors most applicable to governance and control in each scenario. The resulting comparisons therefore serve to assist with the categorization of geoengineering deployment scenarios, and also to highlight the principal governance and control factors arising in each.

I make little attempt to ensure that the imagined future conflict-analogues are highly realistic. These suggested scenarios are intended to illustrate a range of possible behaviors, restrictions, and interventions – not to be an accurate prediction of the behavior of the nations or organizations described. Further, I do not attempt to provide any of the following: a formal review of governance literature; an academic summary of conflict generally, or of any specific conflict; or a normative proposal on SRM conduct or governance.

Most references are provided to supply context, not to support individual points of argument. Accordingly, I make wide use of readable, non-academic sources (news reports, etc.), to provide accessible background information.

I briefly conclude by discussing some of the advantages of this approach – and I suggest possible directions for future work.

1. The Rogue State

A governance "disaster scenario" commonly discussed in the general literature is that of a "rogue state" actor, deploying SRM in defiance of international opinion (Millard-Ball 2012). A parallel to this situation is perhaps that of Iran or North Korea, both of which have continued to develop nuclear weapons

capabilities despite global efforts to stop them. In each case, a combination of sanctions and talks has been used to confront such actions (Rosset 2013). In neither case, however, has a full resolution to the situation been achieved. Despite the lack of a conventional military response, Iran did suffer a notable, highly targeted cyber attack of questionable legality (Zetter 2013). This attack is discussed in other sections.

A small nation, such as Tuvalu, may be able to initiate geoengineering deployment as a rogue state, but that would be merely symbolic. The requirements of a sustained, well-managed SRM program are beyond a small threatened state, because the costs would be in the billions of dollars (McClellan, Keith, and Apt 2012) A more realistic candidate is Bangladesh, which, although poor, has a sufficiently large economy ($122 billion GDP – IMF 2013) to be able to configure a geoengineering program that would be sustainable at scale (McClellan, Keith, and Apt 2012), perhaps costing as little as $1bn per annum. Bangladesh is also similarly affected by climate change to Tuvalu. The risk of heavy loss of life, land, and economic productivity could see a future Bangladesh willing to take great risks to protect itself in a changing climate.

How would the world react to a desperate Bangladesh, willing to deploy SRM to hold back the Indian Ocean? A delicate political balancing act would be required. Bangladesh would be unable to directly challenge the military might of China, India, or Pakistan, all of which are nuclear armed. So, for practical purposes, it must be assumed that the geoengineering program would not anger its near neighbors sufficiently to prevent deployment by means of military strikes, and that any economic sanctions were insufficient to change the country's course of action. Provided the neighboring nations are benefiting, sympathetic, passive, or neutral, inaction is conceivable. Practically, Bangladesh is able to act independently.

Overflight rights are not essential, as Bangladesh is situated north of the Equator, with open ocean to the south. This would permit an injection regime that might not be ideal, but would be viable (McClellan, Keith, and Apt 2012). Its airspace availability might assist Bangladesh in negotiating for any scientifically-preferable flight paths over neighbors' air space, as no "ransom strip" exists.

Beyond its immediate and powerful neighbours, the question of international reaction to Bangladesh's intervention would likely be determined predominantly by the interests of those nations seeking either to intervene or to acquiesce. A starving or flooded Bangladesh would attract a degree of sympathy. However, it would be likely to experience strong pressure to stay within the environmental targets of the rest of the world (temperature, precipitation, ozone, etc.). If Bangladesh were seen as being a unilateral actor working for a common good, it would attract significant support, at least tacitly. Token international protests might be expected, and potentially some legal or Security Council maneuvring could be anticipated. This might be "gesture politics," aimed more at recording a public posture of indignation at unilateralism, rather than actually intervening to prevent deployment. In practical terms, having Bangladesh riding roughshod over international norms would be convenient for states that would benefit from geoengineering, but whose populace might be resistant to it. An obvious example would be Western European states. These nations often have strong democratic traditions, and an active civil society and environmental movement. Powerful actors within these societies maintain disdain for geoengineering, which has been effective at delaying even harmless research (Marshall 2011; Hamilton 2012). This stance could prevent pragmatic and responsible action. An end to devastating heat waves and crop failures might be welcomed by a populace or government even as it remained publicly militant against geoengineering.

The ability of politicians and bureaucrats to engage in pious and vain protest against Bangladeshi interventions (even while enjoying the benefits) might prove expedient for them. Bangladesh could be seen as doing the dirty work of a dozen major powers – perhaps whilst attracting quietly executed technology transfer, trade, or aid deals to smooth the process. It is important to note that this covert

support would afford a seat at the table for economically stronger nations. Through a process of open, impotent condemnation morphing into tacit support, Bangladesh's SRM program could become more like a proxy war, as discussed below.

2.The Technocratic Intervener

The successful conduct of a geoengineering program suggests the need for competency not only in delivery, but also in monitoring and control. There is a range of possible examples in recent history that create a neat parallel between geoengineering and war, when the position of the technologically competent intervener is considered. The UK intervention in Sierra Leone (Lewis 2005) and the recent French intervention in Mali (Doyle 2013) are examples. In each case, a developed nation stepped in to deal with a local conflict, utilizing the advantage of vastly superior technology. In wars principally fought with small arms and light vehicles, the presence of the UK and French militaries was decisive. Broadly speaking, there was no clear and robust international action in either case, beyond the intervention of the former colonial power. Accordingly, there are precedents for unilateral action from developed nations to solve problems beyond their borders without international opprobrium or backlash.

What are the implications for geoengineering in this context? One could imagine a wealthy and competent state, with advanced scientific and engineering capability, conducting a geoengineering program alone. This might be possible even without the motivation of an existential threat. Israel offers one possible candidate. It has an advanced technology and science sector, is relatively wealthy, and has an established history of acting with some indifference to international opinion. Israel's main strategic considerations stem from regional aggression and the need to maintain United States financial and strategic support (Jewish Virtual Library 2011). In many cases, it has demonstrated a willingness to act in defiance even of the U.S. (*Times of Israel* 2012). Therefore, it can be assumed that any Israeli geoengineering program would not pose a strategic threat to the U.S. or (to a lesser extent) other major world powers. Israel would also need to be mindful to keep its neighbors' interests secure in such a program. In this regard, access to fresh water is a major consideration, but the maintenance of economic and political stability among its Arab neighbors is also important. Indeed, a local strategic interest is likely to be essential in encouraging Israeli action, as the costs and political risks would be substantial.

The practicalities of an Israeli deployment would be challenging, with overflight rights posing a particular problem. Air corridors to equatorial latitudes could potentially be established through Egypt, which has been on largely workable terms with Israel (BBC News 2011a). As a militarily advanced country, Israel has the means to seek overseas bases or carriers from which to operate. An Israeli geoengineering program could be carried out with a degree of impunity, while the nation continues its tradition of batting away criticism of its policies. Provided there is no regional or global destabilization as a result, such a technocratic program might be accepted from a scientific point of view, while perhaps attracting a degree of political posturing from opponents. In a scenario not unlike the "Rogue State" discussed above, the program may continue unmolested, but perhaps with greater trust from world powers than would be afforded to a less advanced, more desperate nation.

3. A Coalition of the Willing

Recent research (Ricke, Moreno-Cruz, and Caldeira 2013) has identified potential situations where a power bloc might conduct geoengineering unilaterally, setting the temperature at a level that suits it. In practical terms, there would be nothing to stop other power blocs intervening "over the top" with positive or negative radiative forcing, whether overt or covert. Disadvantaged parties would also have the power to engage in belligerent disruption, through terrorism, sabotage, or military action. In practice, all actors would have strong incentives to resolve the issues through negotiation rather than intervention. Additionally, the governance would likely be much more nuanced than that considered by Ricke and her

collaborators. Subtle human factors would play a significant role. Ties of language, ethnicity, and personal friendship often exert important influences on international negotiations (Joseph 1997), and nations are rarely influenced by only one bloc. Nevertheless, it can be expected that functioning power blocs might emerge, and global consensus of opinion might not be achieved. Military and economic power is likely to be instrumental in such a situation, as Ricke has rightly identified.

Military analogues can be considered in this situation. The second war against Saddam Hussein by the U.S. and its allies was referred to by the phrase "coalition of the willing," and it is an appropriate governance model to consider for geoengineering. It is conceivable that a relatively large bloc of nations could join together – likely led by a superpower – to conduct such an intervention. In the Balkans, NATO provided the formality and cover for a significant multilateral intervention (NATO Library 2015). Whilst NATO is a formal treaty bloc, it is still in principle a coalition of willing nations, although not an ad hoc alliance as was the case in Iraq (to be discussed later). There is, therefore, a relatively established pattern in recent times of this multilateral style of intervention, particularly that led by Western powers. As a further example, Libya offers a relevant model for a more limited coalition and a more limited conflict (see BBC News 2011c).

At various scales of conflict, assistance provided might include not only the obvious strategic support (either money or "boots on the ground"), but also more specialist support such as satellite imagery, logistics, nuclear, biological, and chemical (NBC) warfare specialities, and so on. Accordingly, it is conceivable that an intervention force in geoengineering could be built from a loose coalition of rights, materiel, and resources, rather than by having a clear power bloc of intervening nations. This model may appear "fuzzy round the edges" – as countries involved in such scenarios give support or resistance on a continuum, rather than being in-or-out of a power bloc. Support provided can include overflight rights, refuelling, land transit, bases, security, training, computer time, and so on, to facilitate a large multilateral effort. However, cooperation in any such future coalition might not be a natural choice – as in war, interventions have costs. First, there is the issue of direct participation costs: the "free rider" problem. However, the material costs to any one country in a collaborative effort would likely be small, and political costs might far outweigh these. If, for example, the Arctic states (the Nordics, Greenland, Canada, Russia, and the U.S.) were to commence geoengineering, there might be robust opposition – such as from China and India. Potentially supportive nations, such as the UK, might be reluctant to join in the effort – but more likely because of political costs, not economic ones.

It is likely that any nation seeking to conduct geoengineering would have an advantage in the outward appearance of multilateralism. The more international the action, the better it would be able to resist challenges. It can be expected, therefore, that some support would be very publically provided. This might be accompanied by cajoling and bullying behind the scenes – such as with the U.S. pressure on Mexico prior to the second Gulf war (Associated Press 2003). In this regard, a "coalition of the willing" is perhaps one of the most likely formats for a sustained geoengineering program. The ability to provide "soft support," such as overflights, would allow weakly supportive governments to provide assistance. Even actively resistant nations might provide monitoring, scientific scrutiny, and other passive assistance, giving them an ambiguous status in the process – which might be politically convenient.

A coalition is perhaps a natural exit for the "rogue state" or "Greenfinger" models, both of which are likely to be unstable in the longer term. Private individuals do not have organizational momentum, and a rogue state might lack a stable and well-funded regime; either would likely be incapable of acting reliably on decadal time scales. Any unplanned and disorganized end to an SRM program risks termination shock (Royal Society 2009). Termination shock is so dangerous that a backup strategy would have to be on standby to take over the program in the event of its collapse.

An alternative would be a genuine multilateral takeover policy, but it might be much more difficult to get the near-unanimous global agreement needed for this. In any event, the prospect of a 2-4 degree Kelvin rise in global temperature would be a clear and present danger, and a robust preparatory response would be rational to defend against it. In the event of unplanned termination of an SRM program, a scramble to replace it would be likely to occur, with or without prior preparedness. In practice, therefore, any programs that came into existence would involve coalitions.

4. The Superpower

A superpower intervention has some characteristics of the rogue state, and also of the technocratic intervener. The obvious participant in such activities is the U.S., which has a long history of acting at its own will – using a combination of media, alliances, economics, aid, and military power to project its interests around the world (Grossman 2014). Therefore, a U.S.-led geoengineering program is easy to envisage, and has indeed already been the subject of detailed official work in the U.S. for some time (NAS 1992; Irfan 2013). Such a program might be no more the subject of effective international sanction than would America's recent drone program in Pakistan, which was tolerated in practice despite its dubious legality (BBC News 2013b). More distant historical examples include the Reagan-era deposition of Panama's Manuel Noriega in "Operation Just Cause"/ "Operation Nifty Package" (Galván 2012; ShadowSpear 2011) or the support for the Iranian coup (Kinzer 2003; compare Kazemzadeh 2004). The U.S. is gradually losing economic ground to China (*Economist* 2011), although its military remains far stronger, and will be for some time (Ingersoll 2013). (That said, the military balance between the two nations remains the subject of controversy (Kazianis 2013).)

Notwithstanding, the balance of military power, it is conceivable that China might choose to act alone. China is a nation with a considerable scientific establishment and a world-class ability to deliver complex projects despite economic, political, and engineering challenges. Furthermore, it is a one-party state that has a track record of relative indifference to both internal and external criticism (Chen, Matzinger, and Woetzel 2013). In a situation where the Chinese started SRM, the tacit or overt approval of the U.S. might be required. It is difficult to imagine the Chinese running an SRM program in the face of active and determined U.S. hostility. Nevertheless, it is more realistic that China could "set the thermostat" in at least partial defiance of U.S. interests. Such an event might mark a symbolic transfer of geopolitical dominance between the two nations.

China's recent history does not show the same degree of military projection as engaged in by the U.S. Nevertheless, a clear trend can be seen in China toward cyber warfare and electronic espionage (Claburn 2009), which indicates a willingness to take at least non-lethal action to serve its own interests. Further, Chinese influence is expanding geographically, such as into Africa, in a projection of both economic power and the soft power that accompanies it (Xinhua 2013; for an alternative perspective see Brown 2013). Outright opposition from other powerful nations to China's actions would be an influence on any possible SRM program, but in all likelihood there would be no effective force other than the U.S. that could prevent its operation, unless a major coalition applied diplomatic, military, or economic pressure – each of which would come at substantial cost to the participating nations. Accordingly, robust action could be expected only in the case that China's policy would directly and seriously harm the U.S., the balance of non-U.S. global power, or perhaps a major bloc such as the European Union.

An individual nation threatening a unilateral nuclear strike might be an effective threat against a Chinese SRM program, but this would be conceivable only as a last, desperate stand by a country facing catastrophic costs and losses. Despite its own nuclear status, China may be vulnerable in this regard to diplomatic pressure from its nuclear-armed southern neighbors, India and Pakistan, or perhaps even to pressure from smaller nuclear powers, such as Iran and North Korea. In the event that a geoengineering program provided a perceived existential threat to a nuclear-armed near-neighbor, such diplomacy could

well be backed by overt or implied threats of nuclear-armed force. However, through a combination of economic and diplomatic power projection, it is likely that a Chinese SRM program would be executed with the finesse needed to sustain effective international tolerance – whether or not accompanied by token protests.

One possible risk to such a scenario is the lack of Chinese diplomatic projection. China's somewhat isolationist recent history might prove a limiting factor in cultivating the necessary soft-power capabilities required to engage with affected nations. The levers of power that might need to be manipulated to secure consent for an SRM program could include aid flows or population resettlements needed to accommodate changes in agricultural productivity. Whether China could conduct the exceedingly difficult task of keeping all the diplomatic plates spinning remains to be determined. Accordingly, a rather disruptive international situation might arise in the event of the launch of a Chinese SRM program, whether or not other nations could realistically act to prevent it. It is conceivable that the rest of the world could be left to deal with the consequences of an SRM program instigated by China, without offering much direct support or effective resistance. If, however, the outcome were tolerable or beneficial for the rest of the world as a whole, the Chinese might be afforded a high degree of autonomy in the matter, as would potentially be the case in the Technocratic Intervener scenario.

5. The Proxy War

Wars are not always conducted at the behest of the states waging them. The history of the twentieth century, in particular, is littered with examples of client states, or factions within them, waging proxy wars. Autocratic governments are often imposed or supported by major powers. Examples include Chile (Kornbluh 2004) and Iran (Kinzer 2003). Many Middle Eastern states, such as Egypt (Al Jazeera 2013) and Iran (Gasiorowski and Byrne 2004), were at times propped up by U.S. military and financial aid. The autocrats and guerrillas supported have often waged wars at the behest of, or with the consent of, their paymasters. Afghanistan is perhaps the classic Cold War example of this (Borer 1999). Many other states have engaged in proxy wars without the need for puppet governments (e.g. Colombia vs. FARC) (Drost 2010).

A similar scenario applied to SRM could involve the actions of an oil-rich but less populous Gulf state. The covert or overt motivation for action might be an attempt to allay concerns that continued oil extraction was environmentally unsustainable. A state that exemplifies these relationships in the Gulf is Bahrain. To a greater or lesser extent, it is a client state of the U.S. (Abdul-Hussain 2012), but it is also propped up by Saudi Arabia (BBC News 2011b) – itself a close U.S. ally, at least until very recently (Gardner 2013). The current regime has been recently threatened by a Shia uprising, which was suppressed only with the help of a Saudi intervention. This was itself predicated on the U.S. turning a blind eye to repression, in order to secure its strategically important military base in the country (Abdul-Hussain 2012). Bahrain is heavily vested in the global oil economy, but is also vulnerable as reserves dwindle. Paradoxically, therefore, it will face greater economic pressure and simultaneously a need to maintain the oil-based economy as time advances. This could make it an ideal candidate for fronting a U.S.-led geoengineering program, at least from a political point of view. In some regards, Bahrain shares these proxy characteristics with Israel, albeit without its technological sophistication.

All of the above demonstrates that superpowers are capable of getting smaller states to do their bidding, by fair means or foul. Applied to geoengineering, it is conceivable, therefore, that an individual client state or a selection of similar powers could be co-opted by a superpower to instigate SRM. One could, in modern times, envisage Bahrain acting in this manner, but it is possible that various states that have been susceptible to U.S. intervention in the past, such as Mexico (McClure 2003), could be similarly influenced. A veneer of actor self-interest would be necessary to ensure the credibility of the proxy action, and the sponsoring nation might engage in a pretence of opposition. How sustainable such two-faced

behavior from the sponsor would be is highly questionable, and the façade might reasonably be expected to fall away in due course, once deployment was accepted by other nations, perhaps reluctantly, as the norm.

6. The Unidentifiable Actor

The cyber war between Estonia and Russia (BBC News 2008) and the U.S./Israeli attack on Iran's centrifuges (Zetter 2013) have features that could be analogues of a program of concealed geoengineering activity. Without cast-iron proof of enemy action and directly-attributable physical harm, publics in the defending state are unlikely to support the clear risks of war, whether military or economic, as a response to an SRM program.

How could a geoengineering program be concealed? There is a clear difference between concealing geoengineering (which would essentially be impossible) and concealing its deployment (which might be feasible). Geoengineering-adapted planes look not unlike conventional jets (McClellan, Keith, and Apt 2012), and they could be mingled within normal air traffic. Their flight paths might be suspicious to an educated observer, but not all the earth's airspace is well covered with radar, and not all those powers who could investigate might wish to. This is particularly the case if program efficiency or cost were compromised to aid concealment. Similar scenarios are envisaged by the improbable "Chemtrails" conspiracy theory (Watson 2001). Studies have shown that the addition of SRM precursors to jet fuel is impractical (Laakso et al. 2012), but the concealment of dedicated SRM aircraft among normal freight, charter, or passenger traffic is not necessarily implausible.

Planes dispensing gases, as opposed to aerosols, directly would not necessarily have any easily detectable emissions – there might be no visible "Chemtrails." It is additionally possible that other distribution methods could be used. If concealment, not cost, were the primary consideration, then otherwise uneconomic solutions (such as launching balloons (McClellan, Keith, and Apt 2012) from cargo ships in the open ocean) would potentially be appealing. With some engineering effort, a ship-borne gun system could also be concealed. Whilst there would be no disguising the actual launch to any nearby observers, the ocean is a large and often empty place. It is possible that the vessels concerned might be separated by hundreds or thousands of miles from other shipping, making a "shoot and scoot" operation viable. Concealing the physical lift would not be the only significant challenge, and information concealment would also be essential. False flag operations, forged paperwork, etc., would likely be routine practice in such a program. This might not be sustainable in the long term, but it might be sufficient to allow plausible deniability for long enough to get temperatures down. Any reduction in temperatures from SRM would make "termination shock" inevitable upon its cessation – essentially locking in a geoengineering program for at least the medium term.

Who would wish to conduct such an operation? In short, any nation or group of nations that wished to lock in a geoengineering program without wishing to be subject to scrutiny or sanction. A range of plausible circumstances is conceivable: for example, an informal federation of states with low-lying populous areas (Tuvalu, Bangladesh, and similar nations are possible candidates). Each nation acting individually, or even within a power bloc, might lack the international gravitas and military power to be able to unilaterally create a successful SRM program. However, success might not be important. The only goal need be to create termination shock. From then on, the need to secure a stable climate would take over, and more powerful countries would be compelled to act. An alternative scenario could include fossil-fuel rich states (e.g. OPEC nations), looking to secure an environment conducive to continued greenhouse gas emissions, or agricultural nations looking to optimize yields. Finally, a rogue state or "Greenfinger" geoengineer could also choose these methods. There is always the possibility that material greed, aided by deception, might be a feature of a deployment program. An alternative (although unlikely) financial motivation could be a form of ransom. In a scenario where a geoengineering program was

initiated covertly, the threat of termination shock could theoretically be used to extract payment for its continuation. The cost associated with creating such lock-in, and the relative ease with which the program could be replaced by technologically advanced nations, mean that such a scenario would likely need other motivations than simple financial gain.

7. The Terrorist

Terrorists are portrayed as renegades and criminals. The label may be a function of media and political convenience (Norris, Kern, and Just 2003), as terrorists typically enjoy wide support within a local population or community. This offers them the advantages of concealment, funding, and other support. They are usually the tip of a much longer spear. Accordingly, "The Terrorist" scenario offers parallels with the familiar "Greenfinger" geoengineer – based on the "Goldfinger" character in the eponymous James Bond book (Fleming 1959).

The typical framing for a Greenfinger is an entrepreneur in technical ventures, such as Richard Branson or Bill Gates (Vidal 2012). With the power to act independently, and potentially at odds with stated international opinion, the terrorist and Greenfinger have obvious similarities. The governance mechanisms that can be used to deal with a terrorist are only partially paralleled, as a Greenfinger is likely to be an overt character (Vidal 2012), whereas terrorists are necessarily either named movements with anonymous actors (e.g. ETA, PIRA) or concealed operators (e.g. Osama bin Laden). However, there are parallels between Greenfingers and terrorist figures who have evaded conventional law enforcement. The perpetrators of the Omagh bombing did not flee, and were eventually brought to justice in a civil, not criminal suit (Hall 2013).

Similarly, Greenfingers might experience a combination of arrest threats, travel restrictions, and civil action – similar to the pressure recently applied by the U.S. in the Snowden case (Pérez and De Córdoba 2013). However, these interventions might prove ineffective against a Greenfinger, as the use of companies and trusts would limit the ability of states to apply sanctions to an individual, thus giving this scenario some parallels with the "Unidentifiable Actor" scenario. Furthermore, these legal entities (and potentially the Greenfingers themselves) might be resident in regimes that offer a high degree of confidentiality, or that lack the will or legal framework to act. Tax havens (Gravelle 2015) might fulfil some or all of these criteria. As an example of what can be achieved, Apple has recently demonstrated the ultimate in corporate evasion, with a subsidiary that is not resident for tax purposes anywhere (Worstall 2013) – and various comparable strategies might be available to those looking to extricate themselves or their organizations from oversight or regulation. Individuals might seek to base themselves beyond the reach of whichever law is in question, in states that offer asylum to controversial individuals (such as Russia in the case of Edward Snowden (BBC News 2013a)).

Various naval solutions are also available to an individual looking to escape governance, such as a microstate on an oil platform (e.g. Sealand (Ryan, Dunford, and Sellars 2006)). Alternatives include a ship or hulk based in international waters (CBS 2013). Such a location might serve more than just a legal purpose. An operating base for geoengineering flights could be provided by improvising a runway deck on a scrap container ship or hulk, in the manner of the "Escort Carrier" HMS *Audacity* (Royal Navy Research Archive 2008). Large cargo ships of suitable scale are available for around $20M (Hülsen et al. 2013), which is well within the means of a very large number of wealthy entrepreneurs – and is fairly insignificant compared to the overall costs of running a geoengineering program (McClellan, Keith, and Apt 2012). To consider an extreme case: in a few decades, wealthy individuals may even elect to live in private space stations for the medium or long term, potentially placing them entirely beyond the reach of the law. Even without such elaborate evasion, legal interventions might be very difficult indeed. Attempts to bring notorious criminals (e.g. Al Capone) to justice show how difficult it can be to lawfully engage an

individual with adequate means – necessitating the use of alternative instruments, such as tax evasion in Capone's case (Linder 1931).

The possible legal wrangling could extend to the program itself. For example, lawfully owned planes could be flown empty from an airbase. These could meet in mid-air with a tanker that is carrying stock chemicals, which that tanker plane is incapable of dispensing. The tanker could then transfer the geoengineering precursor chemicals to delivery planes over international waters. With some "decoy" tankers and distribution aircraft added, it would be very difficult to establish which aircraft were and were not operating in the geoengineering program. It is even possible that the aircraft and chemicals could be bought and sold whilst airborne, further concealing their legal situation. The planes need not even be manned. The operation of the whole affair could be controlled by computer program, with instructions beamed in from an unknown location, or by human drone pilots in international waters (Blackhurst 2012).

None of the above would be substantially beyond today's mid-air refuelling or drone technology (McDuffee 2013), and all of it would be very difficult to attack legally. Only military action would be available as an option against a sufficiently well-resourced individual, and the intervention program might have too much tacit support to trigger such a crude and brutal intervention. Even if a military attack were seen as being warranted, it is not beyond the realms of possibility that military defense could (whether lawfully or unlawfully) be provided to a geoengineering air or sea fleet. It is very unlikely that nations would risk pilots' lives to attack a billionaire's defended geoengineering fleet, particularly if there was any degree of tacit support for the program. An overt confrontation is perhaps unlikely, and it is arguably more probable that such robust techniques would be used to encourage consent from the international community, rather than as a genuine attempt to continue in blatant defiance of it. After all, a Greenfinger would likely not wish to spend the rest of his life on a ship, no matter how opulent it might be.

8. Civil War

The use of SRM technology on a global scale is not the only conceivable deployment scenario, and specific consideration has been given to its use in tackling heatwaves (Bernstein et al. 2013). Accordingly, a scenario could be imagined where different jurisdictions within a single country could consider themselves sovereign to alter climate, in a manner akin to weather modification. Local weather modification is already carried out (Demick 2008) – albeit with highly questionable results (WMO 2007). The basis for such an intervention could be a repeat of the heatwaves of the last decade, which killed large numbers of frail, elderly people in various U.S. cities (Drajem 2012), or of the Russian wildfires (Hansen, Sato, and Ruedy 2012). High-quality evidence might not be necessary to shift public opinion in these circumstances – rumors matter to politicians and public alike.

Accordingly, various states or cities might assume a declared or tacit state of emergency, thereupon deploying tropospheric geoengineering rapidly. This might not be to the liking of neighboring states, which might suffer associated impacts, with knock-on effects on weather systems both adjacent and distant (Ricke, Morgan, and Allen 2010; Royal Society 2009). Such climatic or weather links do not necessarily have to be real in order to be controversial, and thus provoke a response. Again, rumors matter. Against a background of interstate sanction or rhetoric, a central government (e.g. the U.S. federal government) might be left powerless by legal restraints, or might be distracted by a related (or even unrelated) on-the-ground state of emergency. Such an emergency situation might include electrical grid failure (e.g. from air conditioning demand), large numbers of heat-related deaths, and a resulting general breakdown of civil order.

Consider the U.S. as an example: In areas of America, hostility toward the federal government is high, with active secessionist movements in some locations (e.g. the Texas Nationalist Movement). If Washington were seen as exacerbating heatwave-related problems by constraining local geoengineering

efforts, it is not inconceivable that federal government workers dealing with an emergency, or attempting to impose central control, could meet determined resistance. Even National Guard troops could face civil disobedience, rioting, and general strikes. In such circumstances, a breakdown of federal government control, analogous to a civil war, might rapidly arise. If the state legislature and its population were united in favor of geoengineering intervention, it would be difficult and risky for Washington to try to enforce its will.

Thus, it might not be clear whether the U.S. federal government would be able to resist state efforts to enforce a geoengineering scheme, even though it would, of course, have the means to block or destroy such an effort. The international community would likely stand back and watch, with little opportunity to intervene. American administrations are typically weakly influenced by international opinion (James and Oneal 1991), so even diplomatic interventions might be off-limits. Intervening in civil disputes (even in smaller nations) is fraught at the best of times, with no guarantee of predictable outcomes, or of resulting stability in the post-conflict situation (e.g. Libya (Joshi 2013) and Mali (Hirsch 2013)). Therefore, even in the absence of violence, the situation arising might be functionally equivalent to a civil war – and thus subject to the same issues and controls. A loose legal framework of national and state law might persist, but personal power politics could well be a dominant force. Any direct conflict between state and federal forces is implausible, but there might be low-level violence at a community level – making it difficult or impossible for federal troops or agents to establish any meaningful control, order, and rule of law.

The resulting situation might look very like a hybrid of mass disobedience and civil war. In this regard, the domestic governance of geoengineering might have to rely on many of the same mechanisms as the governance of civil war. Such governance is often extremely erratic, and may be based more on social, ethnic, and familial ties between factions than on an effectively operating formal governance framework (Joseph 1997). Cultural and ethnic divisions exist in America, with large Hispanic populations in the South and South West. When this is coupled with the possibility of secessionist tendencies, a federal administration would have to tread very lightly in any situation that could mirror a civil war – even if there was no real violence.

9. Bilateral Conflict

The bilateral conflict represents the simplest and most conventional model for warfare. Two states, typically geographically adjacent, conduct a war without the complexities associated with third party involvement. Such states may be widely disparate in power, such as Russia vs. Georgia (Tavernise and Siegel 2008), a conflict that was complicated by the involvement of non-state paramilitaries.

Consider a situation where regional or global SRM schemes could offer a focal point for bilateral conflict – whether military or political. The Indian sub-continent would be an obvious location, as nations might battle to trade off real or perceived threats of flood and drought. Pakistan might try to reduce flood risk, whereas India might prioritize avoiding disruption to monsoon rains. It might be irrelevant whether regional or global powers have strong interests in the situation, because (by definition) a pure bilateral conflict can directly involve only two parties, and only a nation with a sufficient combination of means and will can act as aggressor. Pre-existing tensions could rapidly escalate, as India and Pakistan have a fairly strained peace, and tensions (such as over Kashmir) have the potential to escalate – as demonstrated by the 2001-2002 nuclear standoff (Coll 2006). However, the involvement of nuclear-armed parties might engender restraint when it comes to outright warfare, by the principle of Mutually Assured Destruction (Myhrvold 1999). However, this might also have the companion effect of reducing the options for external intervention in a bilateral dispute – as even capable military powers might be fearful of provoking a nuclear response. Sanctions might be a possible diplomatic tool to enforce international will on a perceived errant party, or alternatively to attempt to enforce calm on two febrile nations.

Support for negotiations, and possible schemes for compensation or legal redress, could instead be used to control the parties' desire to set up geoengineering regimes that benefit a domestic audience whilst substantially disadvantaging the interests of foreign countries. Threats of unilateral geoengineering could therefore be used or threatened as a lever of power to secure aid flows, in a halfway house between credible strategy and clandestine blackmail. Attempts to extract international aid might ultimately fail, however, due to the sheer scale of the settlement that might be required. It is not inconceivable that the losses projected from climate change, with or without geoengineering (Stern 2007), might be beyond the capability of the international financial institutions to rapidly fund (Oxford Analytica 2009), potentially necessitating a new global financial settlement to break the deadlock. Otherwise, the world might be left with a tinderbox bilateral conflict situation, with no economic means of resolving it. Unless and until a large-scale regional nuclear or conventional war were threatened, the international community might have few options.

The world might sit and watch as tensions and damage escalated, and the belligerent nations argued and postured, started geoengineering, or possibly descended into a significant war. In this regard, governance of war and governance of geoengineering would merge into one. The most effective response might be to establish a global geoengineering consensus, rather than to focus on defusing a single conflict – and it could well be such a flashpoint that would trigger a more internationalist geoengineering program.

10. Internecine Conflict

In parts of the world, different racial and religious groups lead dramatically different lifestyles in similar territories. For example, in the Sahel region Arab nomads are often ethnically, religiously, and economically distinct from their black African countrymen (Library of Congress 1996). Governments often under-represent sections of society – both in Africa, and beyond. Examples include South Africa under Apartheid, and modern Bahrain (BBC News 2011b). The Sahel region is currently poor, with little prospect of rapid development. Thus, it is unlikely that countries in this region would seek to commence global SRM geoengineering alone. However, a regional scheme might be plausible (Bernstein et al. 2013).

When it comes to setting the SRM thermostat, external actors might seek to support particular groups' interests based on ties of religion or race. A pan-Arab coalition might end up facing off against a pan-African coalition, displaying some features of a bilateral conflict and some of coalition approaches. Alternatively, key states such as South Africa and Qatar might seek to take sides, giving rise to features comparable to a proxy war. The history of human conflict shows that ethnic divisions can rapidly open up in conflict situations – often with spiralling tensions or an explosion in violence that outpaces the world's diplomatic system. The post-election violence in Kenya (Al Jazeera 2008) and the tribalism of the Rwandan genocide (Anglin 2001) show that contemporary Africa remains prone to sudden eruptions of ethnic conflict. In such a situation, a cold or hot war over a regional geoengineering intervention might be seen as an "African problem" not meriting external intervention. However, it seems much less likely that a global geoengineering program would be viewed as a solely regional concern.

A nation such as South Africa might have the economic and technical mettle to embark upon global geoengineering on behalf of a sub-Saharan African coalition. Nevertheless, such a small nation could not beat down the world community – unless it were facing an existential threat that forced it to act in a belligerent fashion (as described in the Bangladesh "Rogue State" example). However such a confrontation played out, the likelihood is that cultural and ethnic divisions in the wider region would end up playing a greater role in the emerging geopolitics than do the interests of the population in the flashpoint Sahel area. These vulnerable populations might provide a pretext for conflict over SRM, but on the evidence of previous conflicts, their interests could ultimately be subverted in a wider power game. Those living on the frontlines are rarely the victors in war.

11. Global Ideological War

Wars are often motivated by ideology, which may be genuine, or adopted out of expediency. In the widely quoted words of Friedrich Dürrenmatt, "Religion and political expediency go beautifully hand in hand." Religious and cultural divisions are frequently lines of demarcation between sides (Peacock, Thornton, and Inman 2007). This has been true throughout history, with the Crusades being a notable example. However, the Crusades involved a more complex patchwork of alliances than might be assumed (Asbridge 2011). Since the advent of global transit and communication systems, more geographically disparate followers of ideologies have been able to act in concert. Two notable examples that define the genre of recent global ideological wars are the rise of communism in the twentieth century, and the increasing prominence of global Islamism in the late twentieth and early twenty-first centuries – both of which notably transcended linguistic and ethnic ties.

Whilst not necessarily characterized by a full-on civil war, there was (in at least some states) an element of violent struggle in the rise of communism (e.g. China (Jacobs 2009)), followed by frequent brutal repression in the early decades of its application, leading to mass deaths – particularly from starvation (Yang 2008).

In current times, the rise of violent Jihadist and Islamist ideologies has affected a broad sweep of the globe. Named Islamic Republics have been established in the Middle East (Iran), Asia (Pakistan, Afghanistan), and Africa (Mauritania), in addition to other clearly Islamic states that do not use the term "Islamic Republic" formally. Among the above nations are originators and backers of substantial and active terrorist organizations. These nations include Iran (Hambling 2008; Conroy 2009), Afghanistan, and Pakistan (Wander 2008). The influence of Islamist and Jihadist ideology has spread well beyond this geographical region, in both the location of arms-length attacks (e.g. 9/11) and the existence of "home grown" terrorist attacks and movements, such as those in the UK (Gardham 2010). In recent years, Al-Qaeda has expanded membership of its organization by adding franchises well beyond the borders of the countries that represent themselves as Islamic (McKelvey 2013).

A global geoengineering ideology could come about as a result of a loose and potentially quarrelsome alliance of a number of actors listed in previous sections. To illustrate the potential for interplay of a range of disparate actors, consider the following imaginative narrative. During the late 2020s, a charitable trust fund supported by a number of Silicon Valley "Greenfinger" billionaires starts testing solar radiation management technologies. This program commences using private jets, donated by the entrepreneurs. These are adapted to operate off an aircraft carrier rented from Pakistan, stationed in international waters off the coast of Ecuador, but kept close enough to fall under its de facto military protection. The aircraft carrier has a small suite of defensive weapons but is not otherwise combat-ready, having previously been mothballed for cost reasons. The rental is on an "operating costs only" basis, as the Pakistani government is supportive in principle of the work, due to its experience of repeated, devastating floods. After successful trials of the technology, the trust fund opens a public campaign to fund full deployment. Fronted by an alliance of musicians, elder statesmen, and celebrity actors, the trust raises funds online only. To avoid legal problems, all payments are in Bitcoins – and are sent directly to servers on the ship.

The fundraising falters initially. However, after a severe drought in the Horn of Africa, Muslim leaders issue a *fatwa* (edict) commanding support for the operation as an act of *zakat* (charity). To their surprise, their call is promptly backed by prominent rabbis, leading to large donations from the Jewish community, especially in the U.S. The campaign becomes fully funded when a shortfall is addressed by an alliance of island states. A governing body is elected through a global online voting system – with a diverse mixture of scientists, politicians, and elder celebrities. As deployment scales up, strong resistance to the operation is voiced by the U.S., which sends a carrier battle group to loiter near the Pakistani carrier. However, a

drought in Mexico causes a severe water shortage, and Hispanics throughout the U.S. commence a general strike and civil disobedience program, which forces the U.S. government to back down from its threat. The evacuation of the carrier group is disguised as an emergency re-tasking, to deal with an unrelated security situation in South-East Asia.

Whilst the details of such a scenario require a greater leap of the imagination than some others described, many other equivalent futures could be anticipated in which ideology plays a key role. It is certainly conceivable that existing ideological movements may align with geoengineering as a cause. Further, geoengineering itself may serve as a catalyst for new social movements – perhaps in a similar manner to the growth of the original modern environmental movement in the late 1960s and early 1970s. There are many conceivable circumstances in which ideology may transcend pragmatism as a reason to act, and many dramatic events are so seared in the public consciousness that they need no references. Pragmatism does not make people stand in front of advancing Chinese tanks in Tiananmen Square, nor fly airliners into New York skyscrapers. Ideology may, therefore, be a more important basis for action to instigate geoengineering than pragmatism alone. It is most unwise to ignore the role of ideological commitment when considering possible scenarios for the beginning of a global geoengineering program.

Conclusions

The present lack of an extensive literature base on potential unconventional geoengineering scenarios creates difficulties when considering geoengineering deployment and governance. Governance of warfare is an imperfect analogue for governance of SRM, as SRM lacks a prerequisite for conflict. Nevertheless, there are significant parallels, which are demonstrated by this article's consideration of various somewhat speculative scenarios.

The governance of warfare suggests a wide range of analogous conflict types, where power blocs may take roles on a continuum between active support and active resistance to SRM. It must be stressed that active resistance, in this context, may or may not include the use or threat of force: embargoes, trade blockades, sanctions, cyber warfare, and asset freezes are potentially relevant non-military interventions.

Between the possible extremes lie the following options:

- Oppose (or support) SRM without acting.

- Publicly protest whilst offering private support.

- Oppose in principle, whilst offering non-assistive support, such as monitoring, safety and technical assistance, fail-over capacity, etc.

Potential complexities are revealed by my rather limited discussion of each conflict type analogue. Accordingly, I suggest that further, more detailed study of these individual potential governance scenarios should ensue, so as to understand more fully the risks of related situations and the possible options for their management, governance, and control. Such control may be exercised by political, economic or legal means, and each of these merits analysis.

When reflecting on the tools for further research, particular priority could be given to studying legal, treaty, tariff, and other paper instruments – an approach that has been largely outside the scope of this article. Another appropriate investigative technique is the use of "serious games" and resulting game theoretic analysis. A further and more detailed examination of historical examples would also be useful.

The clearest lesson is that the previous tendency to consider only a very limited set of geoengineering deployment scenarios does not reflect the true diversity of plausible futures. This narrow scope may lead to a major weakness in society's ability to anticipate, prepare for, and manage some of the possible future geoengineering scenarios. If social scientists are to help to prepare society properly for the possible onset of geoengineering, the scope of their considerations must be broadened as a matter of urgency. A failure to address this issue may lead to genuine threats to peace, security, and the global environment.

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