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ANALYTICAL ESSAY

The International Politics of Climate Engineering: A Review and Prospectus for International Relations

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Proposed large-scale intentional interventions in natural systems in order to counter climate change, typically called "climate engineering" or "geoengineering," stand to dramatically alter the international politics of climate change and potentially much more. There is currently a significant and growing literature on the international politics of climate engineering. However, it has been produced primarily by scholars from outside the discipline of International Relations (IR). We are concerned that IR scholars are missing a critical opportunity to offer insights into, and perhaps help shape, the emerging international politics of climate engineering. To that end, the primary goal of this paper is to call the attention of the IR community to these developments. Thus, we offer here an overview of the existing literature on the international politics of climate engineering and a preliminary assessment of its strengths and lacunae. We trace several key themes in this corpus, including problem structure, the concern that climate engineering could undermine emissions cuts, the potentially "slippery slope" of research and development, unilateral implementation, interstate conflict, militarization, rising tensions between industrialized and developing countries, and governance challenges and opportunities. The international politics of climate engineering is then considered through the lenses of the leading IR theories (Realism, Institutionalism, Liberalism, and Constructivism), exploring both what they have contributed and possible lines of future inquiry. Disciplinary IR scholars should have much to say on a number of topics related to climate engineering, including its power and transformational potentials, the possibility of counter-climate engineering, issues of institutional design, international law, and emergent practices. We believe that it is incumbent on the IR community, whose defining focus is international relations, to turn its attention to these unprecedented

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technologies and to the full scope of possible ramifications they might have for the international system.

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Over the past few decades, global climate change has evolved from a topic primarily of interest to atmospheric scientists, to a prominent issue in international politics with huge annual intergovernmental conferences, a highly complex array of international institutions, and a vast number of substate, suprastate, and nonstate actors devoted to shaping climate policy. Much of the attention paid to climate change is a function of the immense stakes involved, the scale of future (and increasingly present) risks, the substantial international distributional implications, and the consequences of what has come to be viewed as a divide between the global North and global South. Even as the issue has grown in importance, however, scholars from the discipline of International Relations (IR) have arguably paid insufficient attention to climate change as both a product and a driver of international politics (Keohane 2015).

Today, an emerging set of proposed technologies to reduce climate risks stands to dramatically alter the international politics of climate change. Some of these large-scale interventions in natural systems intended to reduce climate risks, collectively called "climate engineering" or "geoengineering," may be able to break through the collective action problems of greenhouse gas (GHG) emissions abatement and greatly reduce climate risks at low cost (McNutt et al. 2015a, 2015b). At the same time, they pose their own environmental and social risks while potentially turning international climate politics "upside down." Tensions brought about by climate engineering could conceivably lead to international conflict and pose a threat to global security. Although there is currently a sizeable and growing literature on the international politics of climate engineering, scholars outside of IR have primarily produced it, in many cases outside of traditional academic outlets. Furthermore, it is strongly dominated by the theory (or paradigm) of Institutionalism, yet in our opinion, it should be of interest to a wider range of IR researchers, including those who previously have felt little reason to engage with environmental matters.

We are concerned that IR scholars are missing a critical opportunity to offer insights into, and perhaps help shape, the emerging international politics of climate engineering. To that end, the primary goal of this paper is to call the attention of the IR community to these developments. Thus, we offer here an overview of the existing literature on the international politics of climate engineering, and a preliminary assessment of its strengths and lacunae. This paper identifies what we believe IR's leading theoretical traditions could offer to this potentially transformative field and suggests some lines of future inquiry.

Climate Change and Climate Engineering

Anthropogenic emissions of carbon dioxide and other GHGs cause climate change. These accumulate in the atmosphere and lead to higher temperatures, changed precipitation patterns, rising sea levels, more extreme weather events, and ocean acidification. These, in turn, will have large, mostly negative impacts on humans and the environment. The primary policy response has been efforts to reduce GHG emissions, often called "mitigation" or "abatement." More recently, adaptation, or measures to reduce the vulnerability of human and natural systems to climate change, has been embraced by international policymakers as a second key response.

These responses so far appear to be inadequate to avoid dangerous climate change, and there are reasons to be pessimistic about future efforts. Given this outlook, a growing number of climate scientists and policy experts are proposing climate engineering as a third major set of responses to climate change. Researchers conventionally divide these technologies into two categories. Carbon dioxide removal (CDR) methods, sometimes called negative emissions technologies, seek to remove this leading GHG from the atmosphere and store it on millennial timescales underground, in the ocean, or in terrestrial ecosystems. Examples of potential CDR techniques include direct air capture, bio-energy with carbon capture and storage, and ocean fertilization. By contrast, solar radiation management (SRM) techniques involve reflecting a small portion of incoming sunlight away from the Earth, thereby moderating global temperatures. SRM methods include stratospheric aerosol injection, marine cloud brightening, and space reflectors.

Of these proposed climate engineering methods, a few SRM techniques—especially stratospheric aerosol injection—have received much attention due to their apparent highly leveraged ability to reduce climate risks and consequent potential to upend traditional climate politics. Recent modeling indicates that SRM could suppress approximately eighty percent of climate change's expected anomalies in temperature and precipitation at the regional scale (Kravitz et al. 2014). This appears to be achievable rapidly, at low cost, using feasible technology, and requiring minimal resources and territory. That is, current evidence implies that almost any state or even a nonstate actor could theoretically alter the entire planet's climate, perhaps independently of the desires of others. The political implications are potentially enormous.

Some climate engineering methods would entail novel technologies, or novel applications of existing technologies, and may introduce unfamiliar risks. In general, CDR techniques share much in common with existing mitigation approaches such as carbon capture and storage or large-scale reforestation. These would be slow and expensive, and the risks they pose tend to be localized and controllable.[1] SRM methods, on the other hand, would be remarkably fast and inexpensive, and potentially involve risks at the regional or global level. Scientists have identified a number of possible environmental side effects, such as uneven regional compensation of temperature and precipitation, stratospheric ozone depletion, and changes to the diffusivity of incoming light. At sufficient scale, many of these consequences have the potential to impact ecosystems, agriculture, and people. We will consider these and other possible climate engineering risks at greater length in the review section below. In what follows, unless otherwise stated, "climate engineering" refers only to high-leverage proposed SRM methods such as stratospheric aerosol injection and marine cloud brightening, although some aspects of this paper could apply to other proposed methods.

Commentators have also identified several political risks that might accompany the research or use of climate engineering. Some methods are anticipated to be inexpensive enough, in principle, to allow for their proliferation among numerous state and nonstate actors, possibly leading to uncoordinated implementation and disagreements over implementation form, location, timing, and intensity. Research into climate engineering might pose a "slippery slope" that biases future implementation decisions toward the affirmative. Control over technologies in the research or implementation phase raises challenging issues of power, legitimacy, and authority to make decisions. Perhaps most frequently, observers have hypothesized that research or use of climate engineering might unduly reduce the incentive for mitigation (the so-called "moral hazard" concern). Finally, if states or other actors were to implement climate engineering on a large scale under conditions of elevated atmospheric carbon dioxide, then premature sudden

[1]An exception is ocean fertilization, which could cause harm to marine ecosystems.

termination could lead to rapid—and dangerous—climate change (the "termination" risk).

Many of the scholars who discuss climate engineering have considered possible scenarios under which states or other actors might implement the technology. In one, climate engineering could be developed and used only if mitigation turned out to be inadequate. This variously portrays it as an insurance policy, a last resort, a Plan B, or an emergency response. Such a "backstop" strategy might be the product of advance deliberation, crisis (whether real or perceived) decision-making, or something in between. In a second scenario, climate engineering would be deployed as a complement to mitigation and adaptation in order to slow the rate of climate change, to gain additional time to more effectively mitigate, and/or to "shave the peak" off of damages until atmospheric concentrations of GHGs could be lowered. In a third scenario, climate engineering would be deployed on a regional scale, for example, to cool the Arctic to preserve or rebuild sea ice, or to cool tropical cyclone basins to reduce their storm potential. Of course, these three general scenarios are neither exhaustive nor mutually exclusive.

Interest in climate engineering has been increasing rapidly. There are now hundreds of academic publications on the topic, encompassing both natural and social sciences (Oldham et al. 2014; Linnér and Wibeck 2015). The rate of publication has been growing rapidly, with the vast majority of articles appearing since 2010. We identified approximately fifty published articles, chapters, white papers, and reports that significantly consider the international political dimensions of climate engineering. Yet most of these contributions are either anchored in scholarly disciplines outside of IR and/or appeared in the gray literature. In fact, we are aware of only about a dozen works[2] on the global politics of climate engineering published in academic journals or edited volumes that were authored by IR scholars.[3] Of these, only three (by our count) appeared in English-language IR journals (Chalecki and Ferrari 2012; Urpelainen 2012; Zürn and Schäfer 2013).

Existing Literature

Here, we review the existing scholarly literature on the international politics of climate engineering, grouped primarily around key recurring themes found therein. We categorize these themes into three groups: research, implementation, and governance. The categories are not mutually exclusive, as many themes cut across multiple categories, and are simply intended to help organize the wide variety of concepts that have been articulated. Before discussing these, however, we present a brief overview of how the literature has evolved over the past few decades.

Experts first proposed climate engineering in 1965 as a possible response to anthropogenic climate change in the initial United States government report on that topic (Revelle et al. 1965). The relatively few writings published in the subsequent forty years introduced most of climate engineering's central aspects and challenges, such as implementation authority, problematic unilateral action, potential conflict, the distribution of costs and benefits, the "moral hazard" concern, and the "termination" risk. An article by Nobel laureate Paul Crutzen (2006) did much to weaken the taboo against discussing and researching climate engineering. During the following few years, scholars began to consider how such challenges might be addressed by examining topics such as the bottom-up development of norms, the applicability of existing multilateral environmental

[2]These works include Schelling (1996); Barrett (2008); Victor (2008); Virgoe (2009); Benedick (2011); Horton (2011); Humphreys (2011); Chalecki and Ferrari (2012); Humphreys (2012); Maas and Scheffran (2012); Urpelainen (2012); Scheffran (2013); Zürn and Schäfer (2013); Barrett (2014); Dalby (2015).

[3]We define IR scholars as researchers who explicitly engage in those inquiries, debates, and enterprises that are conventionally held to constitute the academic discipline of IR, conceived as a subfield of political science. See Smith (1995) and Maliniak et al. (2011).

agreements, potential new multilateral agreements, the role of intergovernmental organizations such as the United Nations, and possible research and implementation scenarios. A 2009 report from the Royal Society of London was key to advancing this discourse (Shepherd et al. 2009). In the last five years, both the quantity and depth of publications have increased significantly. Some writers have begun to critique some previous assertions (Horton 2011; Reynolds 2015a). Researchers have also made a number of more specific suggestions for governance mechanisms, often based on multilateral arrangements.

Research

Climate engineering research—not only its implementation—has international political aspects. We will discuss three of those aspects here. Primary among them is the concern that serious consideration of climate engineering would undermine the already insufficient efforts toward mitigation and—to a lesser degree—adaptation. This so-called "moral hazard" concern was first publicly discussed by atmospheric scientist Stephen Schneider (1996, 295–96). Schneider recounted the internal deliberations four years prior of a US National Research Council committee as to whether to include a chapter on climate engineering in a report on climate change. Some committee members feared that such knowledge might provide "ammunition" or provide an "excuse" for those who benefited from continued emissions. David Keith (2000, 276–77) later considered this in more depth, including the possibility that reduced mitigation, as a response to climate engineering, could be either socially optimal or suboptimal, depending on how substitution affects the overall risk profile. Since then, most writers on climate engineering have referenced the "moral hazard" concern at least in passing. Some scholars have considered the relationship between climate engineering and mitigation in greater detail, such as by modeling how states might pursue mitigation in response to other states' climate engineering activities (Urpelainen 2012; Manousi and Xepapadeas 2013; Moreno-Cruz 2015; Qu and Silva 2015). More recently, some observers have questioned whether states would truly reduce mitigation in the face of potential climate engineering, or whether all reductions in mitigation would necessarily be socially suboptimal (Victor 2011, 190; Humphreys 2012, 460–61; Barrett 2014, 254–55; Reynolds 2015a).

The second relevant aspect of climate engineering research is a cluster of concerns regarding the effect of research on the likelihood of future implementation. Specifically, many observers have asserted that merely conducting research, or the way in which scientists conduct it, could unduly bias future decision-making in favor of implementation. Most frequently, writers frame this possibility in terms of a "slippery slope" (Keith 2000, 277). Scholars have pointed to two specific mechanisms by which this might occur. First, a climate engineering research program could lead to the growth of political actors who would have a vested interest in expanding research and eventual implementation (Long and Scott 2013).[4] Second, a process of technological lock-in, in which the development of climate engineering technology closes off certain policy options while making others more likely, could create powerful pressures for implementation (Cairns 2014, 651–53). As with "moral hazard," commentators often mention the "slippery slope" but rarely explore it in-depth.

The third and final aspect is the potentially competitive political dynamic that research into climate engineering might unleash. Achim Maas and Irini Comardicea (2013, 43) suggested that, as some countries develop the capacity to implement climate engineering, others may seek to match and even exceed them

[4]But see Bickel and Lane (2010, 26).

based out of fear.[5] Such a capacity race could occur in the absence of actual implementation. On the other hand, they also propose that transparent international cooperation in research could reduce tensions (Maas and Comardicea 2013, 44).

Implementation

Perhaps the most relevant characteristic of climate engineering implementation is its problem structure. The fact that a small coalition of states, a single state, or even a nonstate actor could engineer the climate at a relatively low cost, makes climate engineering a fundamentally different problem compared to mitigation. This was captured by Thomas Schelling (1996, 305), who wrote that climate engineering "totally transforms the greenhouse issue from an exceedingly complicated regulatory regime to a simple—not necessarily easy but simple—problem in international cost sharing." Economist Scott Barrett (2007, 20) has distinguished mitigation as an aggregate effort global public good, and climate engineering as a single best effort global public good. Rational actors typically suboptimally produce the former due to the collective action problem. In contrast, and echoing Schelling, the latter requires coordination only to determine what precisely different international actors should do and who shall pay for it. Martin Weitzman (2015), also an economist, contrasted the core challenge of aggregate efforts, commonly referred to as a "free rider" problem, with that of single best efforts, which he dubbed a "free driver" problem. In many regards, this is a positive feature: climate engineering—despite its shortcomings—may offer a greater chance of success at significantly reducing climate risks than mitigation. This has led to some discussion of potentially beneficial unilateral or minilateral action (Michaelson 1998, 121; Virgoe 2009, 116; Lane and Bickel 2013, 13–14).

However, this aspect of climate engineering also opens the door to numerous problematic scenarios. Scientists William Kellogg and Stephen Schneider (1974) raised this possibility in the first academic publication on climate engineering as a response to anthropogenic climate change. In this and many other early writings, there was a general concern that states might disagree over whether and how they should implement climate engineering, increasing international tensions. Some even suggested that wars could result (Barrett 2008, 41; Schellnhuber 2011; Maas and Comardicea 2013, 43). The possibility of a single actor taking unilateral action to modify the global climate would raise deep questions of legitimacy and could pose serious threats of chronic systemic instability and potentially international conflict. Schelling (1983, 470) was the first to systematically explore the specific case of problematic unilateral implementation in a US National Research Council report. The concern intensified after the publication of articles by Barrett (2008) and David Victor (2008).[6] In particular, the latter considered whether nonstate actors might pursue unilateral implementation, for example by a well-intentioned and wealthy "self-appointed protector of the planet," which he colorfully names "Greenfinger" (Victor 2008, 324). Although most writings implicitly or explicitly assumed that only powerful states might unilaterally implement climate engineering, some scholars proposed that a rogue state or one or more states especially threatened by climate change might take such action (Virgoe 2009, 117; Victor 2011, 167). Although the precise number of states deemed actually capable of SRM deployment remained contested, most observers argued that only a handful of states possessed both the technological capacity and the international standing to withstand the probable reputational damage and retaliation

[5]See also Scheffran (2013, 338).
[6]See also Adger et al. (2014, 777).

that might result (Parson and Ernst 2013, 98–103; Lane and Bickel 2013, 19; Keohane 2015, 23). For example, Barrett (2014, 256) suggested that India might be the country most likely to implement climate engineering alone. Joshua Horton (2011, 63) critiqued the "conventional wisdom" of a significant risk of problematic unilateral implementation, arguing instead that states' incentives would discourage unilateral action and that climate engineering would be dominated by a "logic of multilateralism."[7]

The potential for unilateral action, as well as for more general disagreements over whether and how to implement climate engineering, are not the only means by which implementation could increase international tensions and foster conflict. Climate engineering would imperfectly compensate the temperature and precipitation effects of climate change. Some regions would become or remain warmer or colder compared to preindustrial conditions, or more likely, wetter or drier. According to many observers, even optimal climate engineering would result in "winners and losers"[8]: some states would gain relative to a world without climate engineering, some states would lose, and no state would be unaffected. Such impacts could be a source of instability. At the same time, climate change itself is expected to produce temperature and precipitation effects as well as extreme weather events If climate engineering were indeed able to reduce these effects, it might actually *decrease* international tensions relative to a world with unadulterated climate change (Maas and Scheffran 2012, 193–94; Maas and Comardicea 2013, 41).

Regardless, if, following climate engineering, a state were to experience negative weather events, it could blame the implementing state(s), perhaps even accusing them of hostile intent. Attributing causation to climate engineering would be difficult, but this might not matter. Blame could be cast regardless of whether scientists or the leadership of the victim state actually believed in genuine causation (Scheffran 2013, 338). Victim states—whether actual or merely posturing—could demand compensation, retaliate via traditional means, attack related soft targets, or even engage in counter-climate engineering, a risk that was recognized early (Kellogg and Schneider 1974; Keith and Dowlatabadi 1992, 293; Nightingale and Cairns 2014, 13–15). As a notable contrast, analyst Lee Lane and economist J. Eric Bickel (2013, 18) assert that the possibility of counter-climate engineering reduces the incentives of even powerful states to attempt to monopolize the capacity to implement it. That is, because covert or overt counter-climate engineering would be possible and its potential for use would be common knowledge, states would lack confidence in their ability to successfully engineer the climate without facing effective opposition, which in turn would increase incentives to cooperate.

Some scholars have gone so far as to assert that climate engineering itself could be intentionally used to gain economic advantage or for hostile or military purposes (Kellogg and Schneider 1974, 186; Fleming 2007; Olson 2011, 16; Adger et al. 2014, 777; Lin 2015, sec. II.B.3). States may even suspect—rightly or wrongly—that their adversaries are covertly utilizing these technologies in order to gain the upper hand (Dalby 2015, 196–97). The germ of this idea may originate in the use of *weather* modification for military purposes, which the United States undertook during the Vietnam War. The 1976 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques subsequently prohibited weather modification for such purposes internationally, using a definition of environmental modification that implicitly includes most climate engineering techniques. Researchers have not explored the

[7]See also Bodansky (1996, 318), Lane and Bickel (2013, 15–19), and Dalby (2015, 197).

[8]This phrase was used as early as Kellogg and Schneider (1974, 1163) and was included in the influential Royal Society report (Shepherd et al. 2009, 51, 60). See also Adger et al. (2014, 776).

true potential utility of hostile climate engineering, including specific military applications, in sufficient depth. A handful of writers have expressed skepticism, because climate engineering would be difficult to control, would have only indirect and delayed effects, and could draw in additional parties to a conflict (Maas and Scheffran 2012, 196; Briggs (Forthcoming)). Others assert that the militaries of powerful countries, particularly the United States, will inevitably assume control of climate engineering (Fleming 2007; Nightingale and Cairns 2014). Some actors might regard climate engineering technologies as dual-use, with consequent destabilizing effects (Scheffran 2013, 338). Furthermore, even if militarization and direct conflict are unlikely, the indirect effects of climate engineering could operate as drivers of existing conflicts. Maas and Scheffran (2012, 198) state that "The asymmetric distribution of benefits, costs and risks of CE measures could combine with the security risks of climate change in multiple and unpredictable ways, leading to cascading events and tipping points in the international system."[9]

Two additional relevant international political aspects of climate engineering implementation do not directly relate to either problem structure or potential international conflict. First, as described above, climate engineering in a world of elevated carbon dioxide levels may need to be maintained for a very long time, perhaps centuries.[10] How states, international institutions, or other actors might accomplish this over such a time scale is unclear. Some writers have expressed concern as to whether humanity would be able to maintain such institutional and technical continuity (Schneider 1996, 299), while others have argued that this maintenance would require centralization of authority (Szerszynski et al. 2013). Paul Nightingale and Rose Cairns (2014, 10–12) assert that this dependence will lead the US military to assume control of such "critical infrastructure." Still others, like Scott Barrett (2014, 255), see the "termination" risk as unlikely, given that states will have strong incentives to maintain what appears to be a relatively inexpensive operation. Legal scholar Gareth Davies (2010, 279) asserts that this challenge actually presents an opportunity to encourage states to cooperate globally in order to maintain their own long-term interests. For Michael Zürn and Stefan Schäfer (2013), minimizing the chance of termination is an essential component of any effective governance institution.

The final international political aspect of implementation is the potential exacerbation of tensions between industrialized and developing countries. Independent of whether climate engineering would demonstrably harm them, the latter group may perceive it as a neo-colonial endeavor in which those who are least exposed to climate engineering risks make decisions about its use. John Virgoe (2009, 113) predicted that climate engineering "would raise developing country suspicions that it would divert attention and funds from adaptation."[11] To some degree, diplomats are already expressing such sentiments. The only positions on climate engineering issued by national governments are ones of cautious support for research by the United Kingdom and Germany, and one of opposition by Bolivia (Great Britain Department of Energy and Climate Change 2010; Estado Plurinacional de Bolivia 2011; Schütte 2014). The latter is based in part on the "moral hazard" concern and on the assertion that industrial countries "would be free to experiment with high-risk technologies on the planet we all share, the impacts of which would affect the majority of the countries that have done the least to cause climate change" (Estado Plurinacional de Bolivia 2011, para. 5). Furthermore, national support for a 2010 statement of concern by the Conference of Parties to the Convention on Biological Diversity came primarily from developing countries (Conference of Parties to the Convention on

[9]See also Scheffran (2013, 338); Cairns (2014).
[10]But see MacMartin, Caldeira, and Keith (2014).
[11]See also Humphreys (2012, 462).

Biological Diversity 2010, para. 8(w); Sugiyama and Sugiyama 2010, 8–9). Along similar lines but from the perspective of powerful states, Nightingale and Cairns (2014) argue that the United States, in particular, would not relinquish control of such critical infrastructure. On the other hand, resistance from the global South may dissipate in the face of genuine impacts from climate change. That is, if climate engineering implementation indeed reduces these impacts, then developing countries, which are highly vulnerable to them, may not be hostile to such action. In fact, if climate engineering turns out to be effective, it could be welcomed by the global South, either as a means to free developing countries from prospective limits on GHG emissions—and thus on economic development—or as a humanitarian intervention by the North in the face of severe climate disruptions (Buck 2012).

Governance

The politics of climate engineering is also manifest in debates over its existing and potential future international governance arrangements. A prominent example of this in the climate engineering literature is the issue of who would have the legitimate authority to implement climate engineering, which in some regards echoes concerns over unilateralism. David Keith and Hadi Dowlatabadi (1992) raised the matter explicitly, and the question "Whose hand will be on the thermostat?" has resonated throughout the popular and academic climate engineering discourses perhaps more than any other issue.[12] By 2009, the influential Royal Society report concluded that, "The greatest challenges to the successful deployment of geoengineering may be the social, ethical, legal and political issues associated with governance, rather than scientific and technical issues" (Shepherd et al. 2009, xi). More recently, sociologist Bronislaw Szerszynski and colleagues (2013, 2812) argued that

> the social constitution of [large-scale] SRM geoengineering through stratospheric aerosol injection would be strongly compatible with a centralised, autocratic, command-and-control world-governing structure, in tension with the current, broadly Westphalian, international system based on national self-determination.[13]

Some commentators have challenged the "essentialism" underlying this latter view and its arguably problematic conceptualization of democracy (Heyward and Rayner, Forthcoming). The governance theme is also on display in discussions of, for example, possible voting rules for future governance bodies and potential means of enforcing multilateral decisions about how much climate engineering to deploy (Weitzman 2015).

To many, this is an issue of international law. Daniel Bodansky (1996) was the first to examine the relationship of existing international environmental law to climate engineering; several others followed. For the most part, his conclusions remain valid: that international environmental law says little on the topic, as it was written without climate engineering in mind; that it generally permits unilateral activity; that a new international institution would be beneficial but very difficult to create; that there is a chance of a premature and counterproductive prohibition; and that climate engineering may ultimately be a political matter. Recently, Jesse Reynolds (2014a) took the position that the language of international environmental law calls for action (including the research, development, and transfer of technologies) to reduce the incidence and effects of pollution (including GHGs and climate change), and as such generally encourages climate engineering research.

[12]The phrase appears to have originated in Goodell (2006).
[13]See also Nightingale and Cairns (2014); Hulme (2014).

If existing international law is inadequate, then the issue becomes how states *should* govern climate engineering at the international level. Once the taboo on discussing climate engineering was broken (or weakened), a consensus emerged that some form of additional governance was necessary, at least before implementation (Shepherd et al. 2009, xi; Rayner et al. 2013). In general, most observers agree that the governance of climate engineering should ultimately be organized on a multilateral basis. Some argue that this should be global, commonly through existing international legal institutions with wide participation such as those of the UNFCCC (Barrett 2008, 53; Zürn and Schäfer 2013, 273). Others suggest that new, typically United Nations-affiliated institutions should be constructed that focus exclusively on climate engineering governance (Lloyd and Oppenheimer 2014, 53). Some writers have made the case that a small group of states could or should perform these tasks (Victor 2008, 332; Benedick 2011; Parson and Ernst 2013, 333–34; Lloyd and Oppenheimer 2014, 47). Other researchers assert that relying on state-centric governance based upon binding rules, especially at this early stage of climate engineering technology development, would be likely to lead to poorly crafted rules, a counterproductive prohibition, or a stalemate, and that instead the next steps are to develop norms from the bottom-up and to coordinate research (Bodansky 1996, 319; Victor 2008, 331–33; Victor et al. 2009, 73–75; Virgoe 2009, 116–17; Benedick 2011, 7–8; Humphreys 2012, 462–63; Parson and Ernst 2013, 324–25; Reynolds 2014b, 284–88). Over time, international governance could become more legalized with expanded membership. Other scholars argue that the climate change research and policy communities should take climate engineering off the table, wholly or in part due to the expected challenges of international politics (Hamilton 2013; Szerszynski et al. 2013; Nightingale and Cairns 2014; Hulme 2014).

Analysis

In the previous section, we reviewed how the literature on the international politics of climate engineering has evolved, noting in particular the key themes and issues that have been articulated and debated by scholars and other observers. One initial conclusion is that, notably, few of those who have written about the international politics of climate engineering have been disciplinary IR scholars, and even fewer have published in traditional academic IR outlets. In this section, we turn our attention to the main theoretical paradigms within IR and ask the basic question, what could IR theory contribute to the analysis of climate engineering? In what follows, we argue that all major paradigms of IR theory can contribute in important ways to the debates about climate engineering.

We offer these considerations with three caveats. First, despite our treatment of these theories as distinct entities, each exhibits great diversity, and the boundaries between them are often unclear. Second, while we believe that each of these has contributions to make to the study of climate engineering, it is important to acknowledge the many theoretical, methodological, epistemological, and ontological tensions that exist among (and within) these paradigms. Investigations into the politics of climate engineering that originate from different theories necessarily entail heterogeneous assumptions and commitments, which in turn may be irreconcilable or incommensurable with one another. The balance of theoretical compatibility and incompatibility is, of course, an ongoing point of debate within IR, a debate with which we do not engage here. Third, we suggest how proponents of these theories might perceive and analyze the international politics of climate engineering, intending to catalyze future dialogue among IR scholars. In no way do we assert that this is how future research will or should proceed.

Realism

From our review of the literature, it is clear that Realist theorists have so far failed to engage in serious analysis of climate engineering.[14] This is consistent with the long-standing Realist tendency to disregard climate change and environmental issues more broadly.[15] While it is true that some considerations of climate engineering emphasize the potential for interstate conflict introduced by these new technologies, Realist scholars have themselves not been directly responsible for characterizing the field as such. Rather, reigning characterizations of climate engineering as a potential source of international instability and disorder echo Realist preoccupations with order and security but fail to draw on actual insights developed by Realist IR scholars.

If theorists turn their attention to Realism's core focus on power, we believe there is genuine potential for Realism to make meaningful contributions to the climate engineering debate. Specifically, we see at least two possible avenues for substantive investigation. First, as evidenced by the literature review, participants in the debate on climate engineering often refer to the potential for states to use such techniques to advance their interests. Commentators frequently assume that such technologies might serve as instruments of power, ready to be "deployed" in the service of national objectives. Yet, a cursory examination of the material aspects of climate engineering technology reveals this to be a problematic assumption. Put simply, it is unclear how climate engineering technologies might translate into actual quanta of influence or coercion.

Climate engineering technologies, if developed, would produce effects that are both spatially unbounded and unpredictable. These features would likely render climate engineering unsuitable for use as a standard tool of foreign policy, since it would not be amenable to the sort of focused, targeted, proportional applications that make up the bulk of power relations among states. The physical impacts of implementation, in terms of temperature, precipitation, etc., would be difficult to predict, and any predictions would be subject to high uncertainty. Impacts would not stop at international borders, and these could affect third parties and even implementing states themselves. Compared to conventional carrots and sticks such as economic aid or targeted sanctions, climate engineering would be unfocused, unpredictable, and likely ineffective.

This would also be true for any attempt to weaponize climate engineering in order to use it for military purposes. The same issues of controllability, unpredictability, and collateral damage (in the broadest sense) would render climate engineering of dubious utility on the battlefield or in broader theaters of combat. Since a key element of military doctrine is situational control, climate engineering methods would seem to offer disadvantageous options for the use of force. It is difficult to see how climate engineering technologies could be of strategic or tactical value in episodes of armed conflict.

Nevertheless, it is conceivable that climate engineering might be employed as an effective instrument of state power in some way, and Realist IR scholars are ideally situated to explore this issue more fully. For Realists, power is *the* key variable in international politics, and Realists have substantively investigated how national power is made manifest on the world stage. Arguably, it is Neoclassical Realists, with their focus on intervening unit-level variables, who might offer the most insight on the (political) power potential of climate engineering. By displaying a greater appreciation for the role of perceptions and beliefs in decision-making, the constraints faced by governments in extracting resources from society, and

[14]An exception may be Lee Lane, who has written several pieces in the gray literature, sometimes co-authored with J. Eric Bickel. See Bickel and Lane (2010), Lane (2010), and Lane and Bickel (2013).

[15]See Lacy (2005).

other interceding factors, Neoclassical Realists are well-equipped to assess whether and how climate engineering might be practically wielded by states to enhance security or to achieve other goals.

A second climate engineering issue ripe for more substantive development by Realists is the possibility of counter-climate engineering. Releasing countervailing quantities of fluorocarbon gases or black carbon into the atmosphere, for example, could theoretically neutralize the cooling effects from stratospheric aerosol injection. Any implementation of climate engineering might be met by a counter-implementation designed either to neutralize the first move or to place the first mover in an inferior position relative to the status quo ante. This is the basis of the perhaps counterintuitive assertion by Lee Lane and Eric Bickel (2013, 18) (described above) that states will be unlikely to expend efforts to monopolize climate engineering capabilities. Overall, scholars have paid surprisingly little analytical attention so far to the concept of counter-climate engineering.

Among IR scholars, Realists have a particularly rich tradition from which to draw for more sophisticated theorizing on the subject. Again, balance of power theory is likely to be especially useful in this regard. In the first instance, counter-climate engineering is based on the idea that one country's implementation could be "balanced out" by that of another country. The strategic implications of the potential to counterbalance climate engineering in kind are considerable. Would awareness of this potential diminish the likelihood of unilateral implementation? Would it enhance prospects for cooperation? Or would it instead provide effective veto power to any state opposed to climate engineering? How would the possibility of counter-climate engineering affect coalition dynamics? Could it inspire a climate engineering "arms race"?

Although the logic of counter-climate engineering, presumably focused on undoing or otherwise responding to climate interventions using similar technologies, would not be identical to the logic of the balance of power, the sorts of strategic implications noted above would be familiar to Realist theorists. As with the question of the practical power potential of climate engineering, Neoclassical Realists in particular are strongly suited to theorize about the implications of counter-climate engineering. Their view of balancing behavior as conditioned by interest, apprehension, and other mediating factors closely reflects the real-world strategic context within which governments would consider initiating or responding to climate engineering. Calculation combined with (mis)perception, (mis)understanding, variable interests, and practical constraints constitute the decision-making framework envisioned by Neoclassical Realism, and it is within precisely this type of framework that choices about climate engineering *and* counter-climate engineering are likely to be made.

Many other themes discussed in the previous section bear a Realist imprint despite the noninvolvement of Realist IR theorists in their development. For example, current discussions about the free driver problem structure inherent to climate engineering align closely with the Realist view of the international system as fundamentally anarchical and self-help. Similarly, potential uni- or mini-lateral action echoes Realist theories of hegemony, according to which joint international action is possible only if cooperation is underwritten by a hegemonic power. Another example is the idea of "winners and losers" common to the literature on climate engineering, which mirrors the relative gains argument that fuels Realist skepticism toward interstate cooperation.

To conclude, in terms of explicit engagement with the topic of climate engineering, it is apparent that the Realist theoretical paradigm has been almost entirely uninvolved up to now. Realist theorists can provide more insight on the role of power in international politics and on the priority of security as states' dominant interest. For Realists, states exercise power in a multitude of ways that shape

the landscape of international relations, and power underwrites multilateral institutions and other forms of governance. Ultimately, scholars cannot understand the international politics of climate engineering without considering both how climate engineering might affect power and how power might affect climate engineering. Although Realist scholars hold no monopoly on the study of power, they are in a key position to elucidate the strategic and security implications of emerging climate engineering technologies including their coercive potential and scope for counteraction.

Institutionalism

Institutionalist IR scholars share with Realists an assumption of rational states pursuing their interests, but see a greater potential for cooperation due to a belief in states' (at least partial) goal of absolute gains. Although Realist scholars have been largely absent from discussions of climate engineering to date, Institutionalists constitute the majority of disciplinary IR commentators on climate engineering. They have approached climate engineering as an issue of incentives: given prevailing incentive structures, international institutions can be designed to channel state behaviors so as to avoid suboptimal outcomes and maximize aggregate welfare. The free driver uni- or mini-lateralism at the heart of the climate engineering problem is interpreted differently by various researchers in the institutionalist orbit. John Virgoe (2009, 116), for instance, describes a positive view in which, "The U.S. might see unilateral action to stabilize the global climate as another of the so-called global public goods that it currently provides on behalf of the whole world." David Victor and colleagues (2009, 71), by contrast, emphasize the possible negative effects: "Geoengineers keen to alter their own country's climate might not assess or even care about the dangers their actions could create for climates, ecosystems, and economies elsewhere."

Institutionalists are sensitive to the international political problems posed by climate engineering research and development and have put forward a variety of possible solutions. Edward Parson (2014, 107–108), for example, outlines a scenario he terms "Pay to Play Linkage" in which mitigation and decision-making concerning climate engineering are explicitly linked. In this, states must carry out substantial mitigation in order to have a voice in climate engineering decision-making. Others argue that the incentive structure confronting states might be sufficient by itself for climate engineering to cause *increased* mitigation—contrary to the expectations of many—with no need for explicit issue linkage (Millard-Ball 2012; Urpelainen 2012). If incentives do require change, Institutionalists typically recommend iteration, diffusion of information, collaboration, learning, and the reduction of transaction costs—all processes promoted by international regimes. For example, Zürn and Schäfer (2013, 7) lay out a detailed institutional design using a variety of strategies to overcome challenges associated with climate engineering research and implementation.

Most considerations of institutional settings appropriate for the governance of climate engineering research to date have exhibited a high level of generality. This is to be expected given the relative novelty of climate engineering. Institutionalist scholars, however, can begin assessing and proposing specific instruments that could help regulate this new set of technologies. For example, observers have frequently commented that environmental impact assessment (EIA) and research registries could function as key procedural mechanisms in the future governance of climate engineering research (Craik 2015). But closer inspection of these instruments suggests they may have significant limitations as regulatory tools (Blackstock et al. 2015). Traditional EIA, developed primarily to evaluate the environmental impacts of discrete projects, may be poorly suited to assess the social, ethical, and

political concerns that are likely to dominate early research proposals and broader programs. Similarly, research registries and other conventional transparency mechanisms may be limited in their ability to promote trust building among states, nonstate actors, and wider publics by their traditionally narrow scope. Institutionalist scholars could play a key role in investigating alternative mechanisms and processes for improving cooperation and governance in this context.

While the common view that climate engineering would produce "winners and losers" is grist for the mill among scholars in the Institutionalist vein, it is not necessarily the end of the story. Because Institutionalist IR theorists emphasize the general priority of absolute gains in interactions between states, interstate cooperation and optimization of climate engineering implementation may facilitate Pareto improving outcomes. Even if climatic "losers" do result, Institutionalist theory identifies side payments in the context of bargaining as a means to achieve mutual gains. Indeed, compensation for harm is emerging as a major issue in research on climate engineering, and Institutionalist scholars could make significant contributions in this regard. Specifically, they could conduct a comparative analysis of different international compensation systems. Such systems might include conventional monetary payment mechanisms, sovereign disaster risk insurance schemes, environmental assurance bonding, and other institutions designed to compensate climatic "losers" and enhance the prospects of international cooperation (Horton, Parker, and Keith 2015). Institutionalist researchers could also explore the different incentives such systems would present to states, researchers, and other actors, and the types of behaviors different systems would be most likely to induce. For example, because climate engineering research presently appears to provide a beneficial public good of large value, international compensation funds for harm from large-scale field research may be closer to optimal than state or civil liability, the latter of which might disincentivize the pursuit of research and the generation of useful knowledge (Reynolds 2015b).[16]

These considerations raise the question of what exactly climate engineering governance should look like, and Institutionalists have begun providing preliminary answers. The regimes that have been proposed are diverse in terms of their membership, voting rules, formality, complexity, degree of legalization, and reliance upon existing international law, but they all seek to shape state behavior in ways that avoid mutual defection, suboptimal equilibria, and other types of noncooperative outcomes, while promoting mutual gains and maximized total welfare.[17] Some Institutionalists have stopped short of calling for formal regimes now and have instead recommended the development of smaller elements that might one day form integral parts of full-fledged international institutions. For instance, Victor (2008, 333) has called for a "'bottom-up' process [of] ambitious norm-setting activities, backed by research and assessment," expressing hope that, "[a]long the way enough may be learned to create more formal treaties or regulatory institutions."[18]

One specific aspect of governance on which Institutionalists could bring their scholarship to bear is the possible strategic dimensions of counter-climate engineering. In particular, they could contribute insights regarding the role of knowledge and information; the effects of uncertainty, time horizons, and discounting; the dynamics of iterative decision-making; the credibility of threats; and numbers and symmetry of actors. One might envision a theoretical division of labor in which hypotheses about counter-climate engineering based on qualitative work by

[16]This characterization of research as a beneficial public good assumes open publication of results and minimal intellectual property claims, which is consistent with emerging norms for climate engineering research.

[17]See, for example, Abelkop and Carlson (2012, 801–802), Parson and Ernst (2013, 334–37), Zürn and Schäfer (2013, 6–9), and Lloyd and Oppenheimer (2014, 53–57).

[18]This focus is also relevant to Liberalism and especially to "weak" Constructivism, both of which are discussed below.

Realist scholars are tested and, if necessary, modified by Institutionalist scholars using formal game theoretic methods. The rationalist assumptions underlying both perspectives would greatly facilitate such complementarity, which in turn would markedly enhance current research on the international dynamics of climate engineering.

As noted, Institutionalist perspectives dominate the existing literature and have already contributed much. Institutionalists could further contribute by using models to scrutinize more closely additional challenges commonly associated with climate engineering. We have already seen some such work in regards to the potential "moral hazard," which should be deepened, and more research would be welcome on putative phenomena such as unilateral action, termination, and the "slippery slope." This research could begin to take account of potential iteration, learning, increased transparency, focal points, and lower transaction costs—all functions of effective international institutions—to assess possible means of neutralizing, minimizing, or otherwise reducing risks. However, Institutionalist modeling to date has tended to assume a blank slate of international institutions for climate engineering. Future modeling work on the international politics of climate engineering would benefit from explicit incorporation of the current international regime complex as parameters of interaction. Furthermore, Institutionalist models of rational action could also be improved by integrating results from climate modeling, both in terms of states' interests, as well as in terms of the expected climate impacts of various state actions and institutional designs.[19]

Liberalism

While Institutionalist theory has dominated discussions of the international politics of climate engineering, some of those writing in this domain draw from Liberal precepts. Although fragmented and mostly inchoate, a Liberal vision of multilateral, transnational, rules-based governance of climate engineering that is consistent with universal norms and embedded in existing international institutions and networks is evident in the literature. For example, legal scholar Gareth Davies (2010, 278) writes, "There is an understandable consensus that unilateral geoengineering is a potentially frightening scenario and that such decisions must be made, if at all, in the context of agreed multilateral mechanisms." He then goes on to suggest that "creating global climate governance institutions is not a necessary price but an actively good thing. It is an extra bonus of geoengineering, not a cost." Liberal IR theory often remains implicit in discussions of climate engineering politics. In particular, scholars of international law, who usually share many fundamental assumptions and central values of Liberal international theorists, have buttressed Liberal arguments about climate engineering.

Liberalism's particular foci on domestic politics, interest formation, and matters of "low politics" such as science and technology could contribute further to debates over climate engineering research and development. Liberal theories of governance, policy-making, and civil society could shed light on how research agendas and priorities are set. And Liberal insights might also offer practical guidance on how some of the key issues raised in regard to climate engineering research might be resolved either domestically or transnationally.

For Liberals, the main problem associated with implementation of climate engineering, as with many other issues, is constraining the potentially harmful exercise of state power. Uni- or mini-lateral implementation is consequently the most obvious threat to global order and welfare. As a result, researchers influenced by Liberal thought have repeatedly stressed the overriding need to restrain unilateralism in order to preserve international peace and security. Moreover, scholars

[19]See Ricke, Moreno-Cruz, and Caldeira (2013).

reflecting Liberal theory generally view unilateralism (or minilateralism) as inherently problematic, independent of whether such action materially harms other states, because it would undermine international norms of consensus and legitimacy. Cooperation and the constraint of powerful states are thus viewed both as instrumental to security and as themselves normatively desirable. For example, David Humphreys (2012, 462) asserts that

> There would also be important issues of fairness and equity if the power to determine world geoengineering policy were to lie with those countries which have benefitted the most from fossil fuels and whose actions have contributed the most to the problem of anthropogenic climate change.

The precise form of multilateral arrangements appropriate for the governance of climate engineering has usually been either left unspecified by Liberal theorists or conceptualized based on existing international environmental law. As noted above, legal scholars have been prominent Liberal commentators on the international politics of regulating climate engineering. For example, Karen Scott (2013, 353, 355) asserted,

> International environmental law provides a basic regulatory framework for geoengineering and serves a valuable function in constraining proposals for large-scale deployment that risk significant environmental harm . . . the creation of a designated forum for debate and regulatory development with respect to all geoengineering technologies is arguably the most apposite regulatory solution.

The relationship among international law, legal norms, and international relations is one key area where IR scholars grounded in Liberal theory could provide particular insight. An additional topic that is ripe for Liberals is the role of nonstate actors and the networks in which they participate in the international politics of climate engineering. Transnational advocacy networks have been well studied in the domains of the environment in general and climate change specifically. However, climate engineering is likely to cut across established political boundaries. To date, those coalitions that support and oppose aggressive steps to reduce climate change risks have largely been silent on climate engineering, yet one can imagine numerous ways in which they might respond to this emerging technology, potentially realigning advocacy networks.[20] For example, will the influential transnational networks that have long advocated for strong mitigation and adaptation embrace climate engineering as an additional means to reduce climate risks, or will they reject it as a threat to their preferred means of action? Could some conservative actors who have so far resisted strong climate action embrace climate engineering as a more market-friendly or ideologically compatible policy alternative (Kahan et al. 2015)? Could new networks of novel constituencies form across existing political divides? Liberal theories of network formation and change could both enrich our understanding of networks in the nascent field of climate engineering, and be conceptually enriched themselves by exploring the novel configurations of actors and interests poised to emerge in this area.

Liberal IR theorists could also contribute substantially to discussions about the relationship between climate engineering and democracy. In particular, what does climate engineering portend for democracy at the global level, to the extent that it exists? Some scholars have asserted that climate engineering by its very nature will "necessitate autocratic governance" (Szerszynski et al. 2013, 2812).[21]

[20]For tentative thoughts on political realignment, see Heyward and Rayner (Forthcoming).

[21]See also Hulme (2014). This is consistent with claims of authoritarian tendencies in global environmental governance more generally. See Heyward and Rayner (Forthcoming).

Among other possible reasons, this could result from the need to rely upon "top-down expertise," the need to apply climate engineering consistently and predictably, and the inability of parties to opt out. Whether this would, indeed, be the case, or whether climate engineering would instead be consistent with polycentric and transnational global governance—which are often seen as at least potentially legitimate, despite their limitations—is a critical issue that Liberal IR scholars could begin to answer. Specifically, Liberals could focus in particular on whether and how climate engineering would promote hierarchy at the unit- and/or system-level, and if so, whether and how such centralizing tendencies might be curbed.

A related issue is the controversy over the emergency framing of climate engineering. Commentators have sometimes framed implementation as a potential response to a "climate emergency," for example, the crossing of a climate tipping point. Critics, however, have attacked this framing as scientifically dubious and politically problematic insofar as "states of exception" triggered by declarations of emergency can lead to abuses of power and illiberal outcomes (Horton 2015). Yet even critics acknowledge that conditions might exist under which emergency action was necessary. In this event, republican security theory, which permeates contemporary Liberal international theory, would have much to say about preferable ways of institutionalizing emergency powers. Traditional republican devices for constraining undue concentrations of power such as balancing, separation, and mixing might serve as templates for distinctly Liberal emergency provisions, for instance, dividing declarations of emergency from delegations of emergency power (Ferejohn and Pasquino 2004). Although proto-liberal republican institutional innovations would not foreclose the possible misuse or abuse of emergency powers by authoritarian governments or hegemonic states, their constraining effects might strengthen the democratic foundations of a Liberal order in the event a climate emergency had to be confronted through climate engineering.

To summarize, much of what we characterize as Liberal insights into the politics and potential governance of climate engineering has, in fact, come from international legal scholars. These contributions could be more deeply integrated with core Liberal IR hypotheses such as democratic peace theory and the influential roles of substate and nonstate actors, leading to a more fully articulated Liberal vision of climate engineering governance. Specifically, Liberal theorists could focus on explaining how various domestic constituencies shape state preferences and actions regarding climate engineering, as well as the potential role of governance beyond the state including the activities of transnational networks. Furthermore, scholars sympathetic to Liberalism have warned about the dangers inherent in the sort of powerful, centralized institutions that governance of climate engineering might require. At the same time, Liberal theorists have also conceived of and promoted a wide variety of institutional power constraint devices that could be adapted to improve governance of climate engineering while strengthening the foundations of a Liberal-democratic global political order.

Constructivism

Although Constructivist IR scholars have contributed virtually nothing thus far to the climate engineering conversation, this is not because Constructivists would have nothing to say on the subject.[22] On the contrary, core Constructivist insights, in particular the sociological foundation and metatheorical orientation of the tradition, have the potential to add fresh ways of thinking to the debate. Indeed, it is likely the perceived "foreignness" of Constructivist ideas among many

[22]Scholars in other fields besides IR who are similarly sociologically grounded and critically oriented have written much on climate engineering. See, for example, Sikka (2012) and Szerszynski et al. (2013).

commentators on climate engineering, combined with the relative obscurity of climate engineering as a subject of inquiry among IR researchers that explains the absence of Constructivist contributions. Another probable factor is the nature of some Constructivism as a deconstructivist, critical, expository approach to knowledge, whose practitioners often decline to make prescriptive statements out of concern that doing so will only reinforce processes of reification.

Nevertheless, Constructivism has much to contribute. So-called "weak" Constructivists are chiefly concerned with the epistemology of influential ideas and how these ideas shape state interests and behavior. In the case of climate engineering, these practitioners may trace the generation of authoritative knowledge, where empiricism will likely dominate claims to authoritativeness. Despite the salience of empirical methods, which particular knowledge set is deemed authoritative is not always self-evident, and as a consequence, some actors serve as gatekeepers for authority. Weak Constructivism could thus attempt to identify which actors have influence and why, potentially by grouping some subset of knowledge generators and gatekeepers as epistemic communities.[23] Indeed, weak Constructivists' work on expert networks and expertise lies at the core of what they could offer to the climate engineering discourse. In addition to empirical knowledge, new norms for climate engineering and its governance are emerging. Therefore, weak Constructivists may seek out and identify norm entrepreneurs. Another topic for weak Constructivist research may be the analysis of the rhetoric within the public and academic discourses, in order to trace which concepts have credence and influence with which audiences.

In contrast, "strong" Constructivism focuses on the roles, relationships, and shared understandings that make up the international social system. To the extent that climate engineering heralds important changes in the intersubjective understandings and social relations that constitute the international system, strong Constructivism would view these technologies as implicated in the transformation of foundational social structures. And to the extent that these technologies are material in nature, their role in processes of change might be regarded as surprising to some strands of Constructivist thought. For researchers grounded in this theory, a key task would be to make explicit the assumptions, constructions, values, and commitments implicit in the climate engineering discourse. This would include adopting a critical perspective toward many of those issues cited as problematic for climate engineering research. For instance, a concern about the "slippery slope" centers on the fear that research will inevitably lead to implementation, yet from a Constructivist point of view, nothing is inevitable in social relations.

Constructivism would view aspects of climate engineering implementation in similar terms. For Constructivist researchers, climate engineering would exhibit no inherent problem structure. Instead, it would be the indeterminate product of agents acting and structures shaping, or (to adapt the phrase from Alexander Wendt) "what states make of it." Whether relations among states (and other actors) would be conflictual, cooperative, or something else would be a function of the prevailing cultural logic and processes of co-constitution between agents and structure. Perceptions, for example of hostile intent, would *be* facts, and responses to implementation such as assertions of blame, demands for compensation, or threats of retaliation, would be cultural artifacts, though no less significant for that.

It is hardly surprising that, when speculating on the possible consequences of climate engineering, researchers and other commentators have tended to proceed starting with present circumstances, inserting climate engineering as an additional policy option, and projecting how it might affect international politics.

[23]See Chalecki and Ferrari (2012).

This approach is understandable and in keeping with conventional positivist conceptualizations, yet it overlooks the critical point that researching and perhaps implementing climate engineering would change the social milieu in which various actors discuss, develop, and possibly deploy these technologies. The availability of climate engineering as an idea if not a collection of implementable technical systems will have discursive and material effects on international political culture and those agents who enact it. Hypotheses based on the current constellation of identities, interests, and structures may be inapplicable to future conditions reshaped by the possibilities of climate engineering. In this regard, Constructivist theory can offer a powerful corrective to much contemporary research on climate engineering.

For example, strong Constructivists, for whom social phenomena are neither fixed nor immutable, would likely express skepticism toward a "moral hazard" concern that was based on the assumption of fixed incentives. It is plausible that talking about climate engineering will, instead of simply hindering emissions cuts, broaden conceptions of the appropriate role of agents in climate politics, redefine possibilities for action, and recast mitigation as inseparable from climate engineering. In a similar vein, concerns about the "termination" problem tend to assume the existence of a widely shared view that any climate engineering should be a temporary measure meant to buy time for more aggressive mitigation, and that this shared understanding of the technology will remain unchanged after years of real-world implementation. Yet it is entirely possible that the routine use of climate engineering might pose a challenge to this intersubjective understanding; present notions of climate intervention as "unnatural" or "abnormal" might well be contested by actors grown accustomed to large-scale interventions, which they view as essentially equivalent to "hyper-adaptation" and, therefore, unproblematic. Although the possibilities sketched here are purely speculative, they underscore the potential of Constructivist theory to see beyond what we take for granted and contemplate alternative visions of the future.

With regard to debates over the governance of climate engineering, constructivist scholars would conceive of governance as international social structure, produced by state and nonstate actors while simultaneously constituting their various identities, interests, and roles as agents implicated in climate engineering. International law, multilateral institutions, research programs, and behavioral norms would represent different, inter-related facets of a governance structure, each characterized by its own unique discursive logics. Norms as understood by Constructivists, especially strong Constructivists, would have more substantive impacts on actors than norms as understood by Institutionalists or Liberals. The "bottom-up" norms proposed by Victor (2008) noted above, for example, would do more than cause actors to alter behavior and perhaps modify interests. From a Constructivist perspective, these norms would help *constitute* actors, shaping their interests and self-conceptions. Insofar as climate engineering portends structural—even systemic—change, up to and including novel conceptions of humanity and nature in the Anthropocene, Constructivism furnishes a unique approach to fully appreciating the potentially revolutionary character of these technologies.

Constructivists might take this approach even further by adopting the so-called "practice turn" in international theory. Practices, according to this understanding, are "competent performances," or regular, meaningful acts, often unarticulated or unconscious, that make up the everyday substance of world politics (Adler and Pouliot 2011, 6). From this perspective, climate engineering might represent a new practice worthy of investigation and explanation, and Constructivist theorists might view it as a fundamental departure from established international environmental practices premised on seeking to minimize human interference in nature. In stricter climate policy terms, they might see it as breaking away from

established and emerging practices of mitigation and adaptation, respectively. In either case, Constructivists could interpret the large-scale, deliberate interventions that would characterize climate engineering as a qualitatively new form of practice compared to previous environmental policy-making activities.

Compared to the other paradigms of IR theory, Constructivism has perhaps the widest range of potential avenues for future work. Theorists associated with its weaker variant may wish to identify and characterize any emerging epistemic communities within the climate engineering discourse. Although there have been accusations of a tightly knit, influential "geoclique," it remains unclear to what extent this is true and, if so, whether it is problematic.[24] Weak Constructivists might also investigate the evolution and impact of norms within the discourse on climate engineering. Turning toward the stronger variant of Constructivism, scholars here could add even more regarding the constitutive nature of norms: norms would be likely not only to channel behavior, but to help fashion the roles and identities taken on by agents operating in this sphere. Their theoretical orientation also makes strong Constructivists well positioned to challenge the largely assumed contours of the climate engineering debate. Concerns such as "moral hazard" and unilateral implementation are built upon beliefs regarding risks, values, states, and legitimacy that may need to be revealed and highlighted. Perhaps most significantly, Constructivism's fundamental emphasis on process and change may allow scholars from this paradigm to comment on the international transformative potential ascribed by some to climate engineering from a unique, theoretically sophisticated vantage point.

Conclusions

The survey of the existing literature of the international politics of climate engineering and our preliminary assessment of it indicate that, although a body of research is emerging, it exhibits some significant shortcomings. In particular, the Institutionalist theoretical paradigm strongly dominates this discourse to the relative exclusion of other perspectives, and those at the margins or outside of traditional IR scholarship are primarily shaping it. Perspectives from outside of disciplinary IR are welcome and indeed vital, and the contributions of Institutionalists are pioneering and valuable. However, as we sought to demonstrate above, other paradigms within the field have potentially unique and powerful insights to offer, and the discipline as a whole could play a much more substantive role in social science research on climate engineering. Put simply, to fully explain and understand the international politics of climate engineering, it is critical that IR theorists, whose discipline is singularly devoted to the study of international politics, become much more active participants in this emerging and potentially highly influential conversation. We believe that each major IR theory can and should make meaningful contributions to the rapidly growing discourse on the international politics of climate engineering. It is incumbent on the IR community, whose defining focus *is* international relations, to turn its attention to these unprecedented technologies and to the full scope of possible ramifications they might have for the international system. If climate engineering field research or even implementation moves forward, knowledge and insights from IR theory, spanning the range of competing paradigms discussed in this article, could play a crucial role in helping ensure that it proceeds on a well-informed basis grounded in our best understanding(s) of world politics.

[24]See Anshelm and Hansson (2014, 139–40).

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