As an introduction to a theme issue on the politics and practices of geoengineering, this paper outlines a framework for thinking about the ‘geoengine’ that underpins concepts of planetary modification. It reviews some of the ways in which geoengineering has been framed as a technological, governance, and promissory discourse and examines the contradictions inherent within some of these framings. Questioning some of the motivations and forms of participation that are evident in the governance of geoengineering, and its current challenge to existing forms of global democracy, the paper speculates on the wider geopolitical implications of operating at the scale of the planet, and what this means for how we currently understand the ‘geo’ in geopolitics. While there is a big mismatch between the restricted decision-making processes around geoengineering and the potential scope and impact of those decisions, there are also opportunities for geographers to make incisive contributions to this debate to change what geoengineering is and becomes as a material–discursive practice. This paper suggests that only by attending to the geo-ontological formations inherent in the fabrication of an engineerable earth, can a new geopolitics be accommodated within political thought that takes account of a much more active ‘geoengine’ that is being opened to political and material modification.

Keywords: geoengineering, climate change, geopolitics, geophilosophy, weather modification, Anthropocene

In 1981 The Guardian ran a front-page April Fools’ day article entitled “A new climate for science”, parodying a British scientist who had discovered a way to manage the weather, that “may make control—as opposed to mere prediction—of meteorological conditions a reality.” The major breakthrough was said to have involved a joint Ministry of Defence and Meteorological Office initiative that “discovered the elusive key to the creation of a variable density electrostatic screen in the troposphere” (Creel, 1981, page 1). From the farce of weather modification in the 1980s to the new politics of geoengineering, where a diverse range of carbon dioxide removal (CDR) and solar radiation management (SRM) techniques are under consideration as viable modes of experimentation, there has been a rapid shift in the scientific and cultural discourses of geoengineering. At present, geoengineering—the intentional modification and/or management of the earth’s climate system—remains, “largely speculative and unproven” (IPPC, 2007), with limited real-world experimentation.

Of the two main geoengineering techniques, CDR is often portrayed as ‘good’ geoengineering because it is localised and incorporates many tested bio-geoengineering practices such as afforestation, peatland restoration, biochar, dark earths, and ocean nourishment through iron fertilisation. Whereas, SRM, which includes surface-based (land or ocean albedo modification), troposphere-based (cloud whitening), upper atmosphere (injection of stratospheric aerosols), and space-based practices (space mirrors and sunshades), are often seen as ‘bad’ geoengineering because of their high-risk, top-down, technological-dependent techniques. Moreover, the effects of SRM on biodiversity and other earth processes...
remain largely uncertain. The criteria for evaluation of both these techniques are synthesised through the calculation and perception of risk.

While geoengineering was once presented as a hoax—a fool’s project—it is now under serious consideration as a potential plan B, in lieu of the perceived failure of the plan A(1) of climate governance to reduce emissions and mitigate the anticipated effects of abrupt climate change. At the same time, adaptation has all but replaced mitigation in climate governance. But, what kind of a shift in planetary discourses has produced a milieu in which proposals to block out the sun or seed the oceans can sensibly manifest as preemptive interventions in ameliorating the worse effects of climate change? And, more broadly, what kinds of technics are at stake in the anticipatory geologics of making new geophysical worlds?

Working with the exploratory quality of geoengineering to produce ‘new climates’, these three short papers in this theme issue employ a speculative approach to thinking with and against geoengineering as a form of planetary management. Cutting across the papers is an investigation into the forms of ‘geo’ circulating in the knowledge economies and practices of geoengineering; in its ‘making’ through deliberate process (Szerszynski and Galarraga, 2013); in the conceptualisation of a new geophysics (Clark, 2013); and, in relation to the possibility of democracy (Szerszynski et al, 2013). Rather than attempt a systematic examination of the field of geoengineering, these papers situate geoengineering in its wider social context in order to open questions about how geoengineering might represents a distinctly new type of geopolitical formation, informed by a reconceptualisation of geophysical processes rather than distinct geographical territories. In parallel, this introduction examines some of the logics that underpin geoengineering, specifically the reconstituted of the ‘geo’ as a territorialising force within environments. This reimagination of the possibilities of planetary modification happens within a broader geohistoric moment of the consideration of humans as geologic agents within the Anthropocene. As such, the possibility of unilateral, yet regionally unequal modification of climate prompts the need to think about biopolitics and geopolitics together; that is, a bio-geopolitics that does not just address power in relation to forms of subjectification and modes of political agency, but extends its consideration to the biosphere, in order to think through forms of collaboration within earth processes rather than outside of them (Szerszynski, 2010; Yusoff, 2013).

Geologics

Geoengineering encompasses a diverse field of scientific practices, even as it seems to be represented by a rather small scientific clique of practitioners. Despite the relative size of the field, the contested and speculative nature of geoengineering has generated an expanded set of discourses in both popular and scientific domains. As both a practice and a concept of planetary change, geoengineering brings together new issues to do with world risk (Beck, 2008), anticipatory governance of futures (Anderson and Adey, 2012), atmospheric securitisation (Whitehead, 2009), innovation and new technologies, and the ethics and politics of “earth systems governmentality” (Lövbrand et al, 2009). Such an aspirational model of ‘whole Earth’ governance follows in the wake of a decade of climate governance that has been characterised by global climate modelling, technological and market-led solutions, failure of international agreements on mitigation, and arguably a lack of democratic and devolved decision making. This shift from the governance of earth surfaces to earth systems can be contextualised within a broader marketisation and management of geophysical and biochemical flows in ecosystems and the atmosphere. Like the climate sciences, geoengineering has generated new epistemological and ontological models of thinking.

(1) The reference to plan B comes from the President’s Foreword in the Royal Society report (2009), although it is not necessarily the view held by the Working Group.
about the earth—or geontologies—which simultaneously engender both the imaginaries and operative spaces that calibrate notions of agency and control in earth processes. As an emergent and heterogeneous set of practices and anticipated technological interventions, what geoengineering is and what it may become are contested questions. What the authors of this theme issue raise in their papers are a set of questions about geoengineering—the geologics and geopolitics of its formation—in the context of both its actuality and its future promises to transform the climate. What these papers have in common is the examination of the underlying motivations and imaginaries of geoengineering as practice (Szerszynski and Galarraga, 2013), a form of governance (Szerszynski et al, 2013), and mode of apprehending and interacting with inhuman earth processes (Clark, 2013).

While notions of a machinic earth have their genealogical origins in James Hutton’s *Theory of the Earth* (1788, page 3), it may be that this metaphorical association that immediately gives rise to the figure of the geoengineer as the agent of control is unhelpful in capturing the diverse set of material practices that characterise the scope of geoengineering’s current oeuvre. However, as political decision making takes on materialist dimensions through the development and testing of these technologies, new geopolitical approaches may be required that depart from classical or critical geopolitics foci on mostly ‘flat earth’ political relations to conceptualise the interactions and thresholds of earth systems (Gabrys and Yusoff, 2012), biochemical flows, and the forces of deep-time processes, in concert with political decision making. This would require the conceptualisation of a geopolitics that considers inhuman forces (anthropogenic and otherwise) alongside more traditional political actors in the making of geopolitical worlds.

The ambition of earth-system governance to make global interventions in the evolution and revolutions of the earth requires an arguably new formation of the relation between geography and power. The logic used to defend geoengineering to its critics bucks this enlargement of the geopolitical sphere, suggesting that there is little distinction between inadvertent geoengineering (anthropogenic climate change) and overt climate engineering, just one of intent. However, there is a definite change in the scale and quality of governance and thus the modes of territoriality that are imagined. The shift is from the generation of predictive climate scenarios to predictive interventions in climate actualities. The framing of geoengineering as overt rather than inadvertent anthropogenic climate change makes the distinction a question of semantics, a difference of degree rather than kind. Yet, while such a distinction of intentionality helps to distinguish geoengineering in specific ways from other human–earth interactions, it puts the emphasis on deliberative action as the guarantor of outcome. Thus, the “governance of geoengineering necessarily involves the ‘governance of intent’” (Owen et al, 2012; Stilgoe et al, 2011). As Szerszynski et al (2013) argue, the formation of geoengineering as a practice of intent raises questions about how technologies are constituted through intended rather than actual effects. But, what does it mean when the intent that is at stake is the intent to govern whole geophysical systems and earth processes, with the express purpose of the global modification of climate? Does operating at the scale of the planet represent a difference in degree or kind in human–environment interactions? The geologics of geoengineering entail both ontological and material shifts in the scope and scale of human agency in biophysical earth forces.

**Geohistories**

While geoengineering is often framed as a mindful response to anthropogenic climate change, the terminology of the Royal Society report (2009) makes a distinction between what should be considered as geoengineering, and what should not: weather modification and anthropogenic experimentation that have inscribed geophysical ‘signatures’ into earth (ballistic missiles, combustion engines, atomic testing, acid rain, fire regimes, biomass burnings, industrial revolutions, and deforestation). Part of this ‘distinction’ is no doubt
pragmatic, to set the terms of reference, but it also enacts an erasure of Cold War histories of weather modification—weather as war machine and geopolitical strategy—that generated highly speculative (and nearly always unsuccessful) experiments. This historical amnesia distances geoengineering from the rationalist fantasies of modernist control that permeated Cold War projects (Fleming, 2010; Fleming et al, 2006), while reinstating the ambition for global reach or technological transformation that sustained their promise. While scientific research on geoengineering is at pains to highlight its cautious and evaluative approach to large-scale technological interventions, such modesty inadvertently champions defeatism towards democratic process. This is tantamount to saying we have not the political will, imaginative largess, or democratic process to respond to climate change in democratic (and just) ways. What geoengineering gains in loosening its historical ties to weather modification projects of the 1950s is an ability to claim its precedence, as a ‘new’ solution to climate change. What it perhaps fails to recognise in its Cold War genealogy is how the promise of former technological innovations already mark how politics are made in the gap between intention and actuality.

The geologic of innovation (located within a broader field of ecoinnovation) is underpinned by a temporal metaphor—geoengineering will buy a little time—for adaptation in the wake of abrupt climate change. Yet, with SRM this is no quick fix. What is not often discussed in the public domain is the level of commitment involved in some technological interventions, while in private, geoengineers discuss issues of ‘fidelity’ to different solutions. SRM technologies such as SPI (sulphur particle injection) have detrimental termination—it is a technological fix that needs to keep on fixing. Fidelity is configured through the promise of technological innovation, despite the potential for abrupt social transformations that might be sparked by rapid changes in climate, which make such long-term commitments dubious. Modelling of interventions suggests that the rebound effect of not continuing along a geoengineering trajectory once started would be catastrophic:

“In the case of inconsistent or erratic deployment (either because of shifting public opinions or unilateral action by individual nations), there would be the potential for large and rapid temperature oscillations between cold and warm climate states” (Matthews and Caldeira 2007, page 9952).

This raises questions about what exactly is the worst case scenario when geoengineering is unidirectional in its deployment, and commits societies to a continued technology intervention into the far-flung future. Matthews and Caldeira estimate from their model runs that abrupt failure or deliberate termination of geoengineering projects in the future would weaken climate sinks and climate-carbon cycle feedbacks and likely result in an acceleration of CO$_2$, leading to extremely high rates of temperature rise, between 2°C–4°C per decade. Like nuclear waste, geoengineering has a technological shelf life that far exceeds the intent and foresight of its contemporary engineers. So, any formation of governance needs to consider how its practices may ‘live on’ beyond their milieu. Such a contingent futurity, which may be characterised by abrupt geophysical and social change, raises questions about intergenerational justice (Svoboda et al, 2011) and the intensification of risk in the context of uncertain futures. The temporal quality of commitment to geoengineering technologies in some instances is irreversible, and yet this commitment is undertaken under the temporal conditions of a state of emergency to establish the validity of its claims.

**Geosphere**

In the embrace of the emergency conditions (‘considering the unthinkable’) there is not just a commitment to the continuance of geoengineered futures—the earth as anthropogenic entity—but to a potentially antidemocratic and unethical (Gardiner, 2011) passage through climate change. As Szerszynski et al (2013) argue in their manifesto for democracy, the political
challenge provided by SRM is not a question of feasibility, economics, or risk management. It is about how SRM is being constituted as a technology-in-the-making in ways that are not consistent with democratic processes. The argument goes, in its most basic form: societies are unable to effectively regulate climate change and so global technological solutions must be found (see IPCC, 2011; Royal Society, 2009). Rather than recognising the ways in which climate governance has exacerbated efforts to democratise climate change decision making and adaptation implementation, and its failure to build democratic governance and institutions into its knowledge-making practices, geoengineering proponents mobilise this inaction to argue for interventionist policies; rather than finding ways to rethink how climate science policy could and should be done differently. When this elision of democratic process is framed as a “knowledge–action gap” (Giddens, 2009), the talk swiftly turns to extrademocratic or exceptional solutions. The advocacy group ETC (action on Erosion, Technology and Concentration), which advocates a moratorium on real-world geoengineering experimentation, suggests that defining geoengineering is a political act (ETC, 2010, page 4). When the politics of description involved in defining what geoengineering is gets reimagined in the context of entrepreneurial business solutions to climate change (the main funder of geoengineering technologies to date), the language becomes decidedly militaristic (the “geoengineering battlefield” is part of Richard Branson’s “Carbon War Room”) and muscular (Shell calls geoengineering a “Game Changer” and the Bill and Melinda Gates Foundation calls it a “Grand Challenge” and has funded geoengineering projects with $4.5 million over three years and plans to invest a further $10 billion). Such framings of geoengineering within an entrepreneurial context of innovation, whether inside or outside the academy, implicitly shape (in Szerszynski and Galarraga’s words) “how problems are framed, how resources are allocated, how research unfolds, and which future trajectories are thereby made more likely” (page 2818). At the moment, they argue, “geoengineering research is characterised by an ‘organised epistemological irresponsibility’, in which such dynamics are not being reflexively addressed and managed” (Szerszynski and Galarraga, 2013).

**Geoclique**

Following the money around geoengineering experiments, proposals, and reviews reveals a small pool of experts—dubbed the “geoclique” by Eli Kintisch (2010)—that are both involved in assessing geoengineering proposals and receiving funding from private foundations interested in the patenting of geoengineering solutions. For example, Ken Caldeira from Carnegie Institute for Science, Stanford and David Keith, from Harvard University have received $4.6 million from the Gates Foundation to run the Fund for Innovative Climate and Energy Research (Ficer), and Caldeira personally receives $375 000 a year to undertake geoengineering research. Both Caldeira and Keith have a number of registered patents for geoengineering technologies: Caldeira is named on a patent (US20090173386A1) with Bill Gates for “Water alteration structure applications and Methods” (2009), patent (US6890497) for “Extracting and sequestering of carbon dioxide from a gas stream” (2005), and David Keith is named on a patent (WO2009155539A2) for “Carbon dioxide capture method for generating carbon credits” (2009) and a patent (US2010064890A1) for “Carbon dioxide capture facility” (2010). What these patents make clear is the intersection of carbon and biotech markets with the technological and scientific development of geoengineering. Philip Rasch (from Northwest Laboratory who received $600 000 from Ficer), Caldeira, and Keith all participated in the Royal Society Report (2009), as well testifying to the US Congress about the need for government funding of large-scale geoengineering (Vidal, 2012) and Keith gave oral evidence to the House of Commons Science and Technology Committee on The Regulation of Geoengineering (2010), thereby using private money to lobby for public funding. While these experts legitimately argue for public financing of geoengineering
research so that it can be more openly scrutinised, there are significant conflicts of interest that suggest that this is not disinterested governance of science or structurally able to provide independent evaluations. Such a concentration of ‘expertise’ in geoengineering research and governance raises questions addressed by Szerszynski et al (2013) about intent to govern.

In lieu of what is deemed to be political failure to reduce emissions by either social change or technological (energy) innovation, scientists involved in geoengineering claim it is “only responsible to think what we would do in face of a climate emergency” (Caldeira, 2010, unpaginated). Yet, this ‘emergency’ looks decidedly like the same business-as-usual approach to expand and generate new market economies of carbon management. The example in October 2012 of a ‘rogue’ geoengineering project off the coast of Canada, when the geoengineering firm Planktos Inc. dumped 100 tonnes of iron sulphate into the Pacific Ocean, exemplifies the proprietary drive towards the patenting of technologies and the emergence of a heterogeneous geoengineering market. This includes venture capital, governments, national funding bodies, private enterprise and a small pool of “expertise” that is distinctly lacking in gender, geographical or societal diversity (see ETC, 2010, page 39). This limited breadth of societal engagement and involvement with geoengineering shapes both the knowledge production process and intensifies antagonisms towards geoengineering as an acceptable practice.

The international Convention on Biological Diversity (2010) is the only international governance body to declare a moratorium on geoengineering, highlighting the unknown effects of geoengineering on biological life. SRM projects, such as solar dimming, raise ethical questions about the biopolitical impact of geoengineering on nonhuman life, and demonstrate how these geotechnics are becoming central to the governance of life beyond the human. The Convention concluded that the only permissible experiments were “small scale” and should have no impacts beyond national jurisdiction. Currently, international jurisdiction is governed by the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, which states that “the term ‘environmental modification techniques’ refers to any technique for changing—through the deliberate manipulation of natural processes—the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space” (United Nations, 1997, Article II). But it further qualifies this by stating, “the provisions of this Convention shall not hinder the use of environmental modification techniques for peaceful purposes” (Article III), which suggests that geoengineering has to be proved to be warlike or geopolitical in intent to counter the Convention. However, what is to be defined as small scale and how the limits of the experiment are to be conceived if the experiment is in the world is unclear. Real-world experimentation raises questions about what it means to move from lab to world, and from model to actuality, and how the sensibility of an engineered planet enables understandings of human agency that has ambitions to act as an earth force.

In a rapidly growing knowledge economy, what possibilities exist for a more democratic engagement with geoengineering, which highlights not just the ethics of geoengineering, but also engages with the processes and practices of problem formation, including its inclusions and exclusions? While the Natural Environment Research Council is one of the few institutions to have undertaken a public dialogue exercise in relation to geoengineering, as documented in Experiment Earth?: Report on Public Dialogue on Geoengineering (2010), could we imagine a more diverse set of governance practices and earth interventions, where publics are not just involved in giving dissent or consent to geoengineering projects, but can interrupt, experiment, and intervene in problem formation? What modes of participative engagement would be necessary to establish a dialogue rather than a monologue with publics? Szerszynski and Galarraga suggest that, within geoengineering research, disciplinary assumptions have
shaped the problem formation and failed to take a properly interdisciplinary approach, and so subordinate the social in addressing what geoengineering could be. The authors ask how an interdisciplinary approach might change the questions that are asked, the practices that are imagined, and the modes of governance that are engaged with. To counter this situation, they propose a model of knowledge making that is more *creative* in its exploration of the norms and structures of knowledge-making practices in geoengineering research.

The humanities may well offer particular critical investigations into these technologies. Artists, writers, and theorists in the Cold War period, working between the spectre of nuclear catastrophe and utopian architectures for planetary survival (Gabrys and Yusoff, 2008; Yusoff and Gabrys, 2011), offered both playful and critical geopolitical accounts of imaginaries of atmospheric control (such as Buckminster Fuller’s 1960s “Dome over New York”). Geoengineering, too, needs its promissory and geopolitical intent creatively explored if we are to move from exceptionalism to more participative forms of governance (Last, 2012). In the first exhibition on geoengineering in Austria, *Cooling Station: Worldwide Geoengineering and Local Weather Making* (2012), creative practitioners and researchers explored proposals for interventions in the climate, and questioned modes of decision making and participation in this planetary experiment. By engaging publics with the processes, technics, and imaginaries of geoengineering, the exhibition opened up questions about the making of models and worlds. As Galarraga and Szerszynski (2012) suggest, new climates may involve new forms of ontological responsibility for ‘making’:

> “the very idea of making the climate has to draw on particular models of fabrication … .These models do not necessarily by themselves lead to specific moral positions … . But they force us to think about what it is to be a being that makes things, and what it might mean to bring the climate into the orbit of human making.”

The praxis of climate making in geoengineering might be characterised by what Mike Fortun (2005) calls in relation to the Human Genome Project, “promissory technologies”. These are technologies that are characterised by the promise to be transformative in the future in ways yet to be known, but are often subject to “overpromising” in terms of their potential. In a revisiting of the ethics of promising, Fortun suggests that his initial attempt to critique such promises by biotech companies was limited, because he did not remain open to the promise. He says: “Promising cannot be reduced to either empty hype, or to formal contract, but occupies the uncertain, difficult space in between” (Fortun, 2005, page 158). Fortun reminds us that, in trying to understand the discourses that emerge with the geoengineering technologies, it is not necessary to proceed from a place of judgment on the technologies themselves, but rather it may be better to find ways of understanding the discursive and geopolitical affects that the promises of those technologies mobilise to transform understanding of what these things *are* or could be. That is not to abandon critique, but to ask, as Szerszynski and Galarraga (2013) do, *how* geoengineering is transformed as an object of concern and praxis of understanding through modes of participation. Or, not to foreclose on what geoengineering might throw up in terms of rethinking the human and inhuman dimensions of geophysical relations (Clark, 2013). If, for example, we began to relish the debate that has been instigated by the spectre of geoengineering, it forces us to reconsider the kinds of geologies that underpin both our conceptualisation of climate change and the kinds of critical physical geography needed to make sense of these imbrications in earth systems (see also Demeritt, 2008; Tadaki et al, 2012; Wainwright, 2010). Considering the new geosocial formations (Clark, 2013) of a broad range of geophysical interventions in earth processes might challenge both our conceptualisation of geoengineering and help us rethink the material ‘ground’ of planetary geopolitics.
Geophysical turn

We might see geoengineering as part of a wider anthropogenic intervention in earth processes or as part of a ‘geophysical turn’ that demands a new kind of geopolitics altogether; a politics that considers not just what happens on the earth, but a politics of geophysical acts within the emergence of earth processes. In this sense, geoengineering involves a form of geontologising: that is, the reconstitution of the earth as a dynamic world object. This is not just the imagination of earth-as-artefact, as in the Apollo images from space or the future-orientated earth objects of climate modelling (Edwards, 2010), but it involves an understanding of the earth as a geoengine that can be altered, modified, and engineered on a global scale. The engineering, then, is not metaphorical, so much as bio-geophysical; it involves the conceptualisation of an abstract, nonlinear biodynamic model of the earth in which atmospheres and earth systems, and even the sun, are imagined as ‘engines’ (albeit organic) open to forms of making. This is not about creating new worlds per se (although geoengineers do now talk about ‘ideal climates’), but about a shift from the earth as a given to the earth as characterised by ideal forms of output, such as climate.

If geoengineering is a governance issue, it is also a geontological issue that requires sustained focus on the geologics that sustain and subtend these engineering strategies, and on the modalities of the earth that construct an a priori engineer-able entity. This is the imaginary of a machinic earth. Yet, this is no ordinary machine, in the mechanical sense, it is one that is bio-geophysical in character. And, so the geoengine, if it is to be conceived as such, needs to be understood more like a Deleuzian machine that regulates and captures flows to generate operative spaces, rather than as a technology that has fixed inputs and outcomes. This raises questions about the inadvertent characterisation of geophysical systems as rational; that is, a geophysics that is coterminous with the rationale of a technological ‘solution’. Similar to the difficulties in modelling nonlinear and dynamic earth processes in climate change, there is a tendency to overdetermine the possibilities of ‘ends’ through the means of production, that are based on constitutive exclusions of radical uncertainties (Yusoff, 2009).

While geoengineering is often framed predominantly as a governance issue—a way of managing science in society—the fundamental geophysical nature of interventions into the geoengine are somewhat obscured. Nigel Clark addresses the geopolitics and speculative geophysics that might be necessary in order to think at the scale of the planet. While geographers might assume a certain priority in thinking the earth, Clark contends, actually the focus on the politics of space, have left the bio-geological aspects of earth systems woefully underthought in human geography. What Clark proposes instead is to take up the opportunity that geoengineering presents to human geographers (geoengineering as provocation) to work at the edges of political possibility, and in the speculative spaces of a new geopolitics of earth processes. Like Fortun, Clark suggests a fidelity to the full promise of geoengineering—opening a space for thinking about geologic agency within earth forces—in order to forge a new geopolitics that includes the actual geophysical earth as constitutive of its world view.

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