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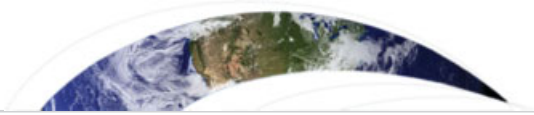

COMMENTARY

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Key Points:
- The debate on climate engineering touches on basic ideological orientations
- Stratospheric aerosol injection may be used to preserve the political status quo
- The relationship between societal and technological development is complex

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Earth's future in the Anthropocene: Technological interventions between piecemeal and utopian social engineering

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Abstract An extensive discussion in the academic and policy communities is developing around the possibility of climate engineering through stratospheric aerosol injection (SAI). In this contribution, we develop a perspective on this issue in the context of the wider setting of societal development in the Anthropocene. We draw on Karl Popper's concepts of piecemeal and utopian social engineering to examine how different visions of societal development relate to SAI. Based on this reflection, we argue that the debate on SAI is fueled not only by the inequitable distribution of its effects and potential atmospheric and climatic side effects, as disconcerting as some of these effects and side effects may be, but also, and perhaps primarily, by its apparent privileging of the status quo and incremental change over a more immediate and radical change in societal organization. Although differing ideological orientations might thus help explain the intensity of parts of the debate, the understanding from which they follow, in which societal development is deduced from postulated technological characteristics and assumptions about a technology's use, hides from view a more subtle understanding of the relationship between technology and politics.

1. Global Change in the Anthropocene

As a consequence of the concerns about extensive documented and predicted impacts of climate change [*Stocker et al*., 2013], a new topic has recently prominently entered the debate on climate policy: the possibility of reflecting some of the incoming sunlight back into space in order to gain control over global mean temperatures [*Keith*, 2000; *Crutzen*, 2006]. Whether societies and their leaders will choose to implement a technology capable of this is uncertain as of now, also because the science on such solar radiation management (SRM) and its side effects is not yet settled. But the debate alone can shed some light on how societies attempt to grapple with their increasingly large leverage over fundamental processes that govern life on Earth in the Anthropocene, the age in which humanity has become a global forcing agent. In this contribution, we present a critical examination of stratospheric aerosol injection (SAI), an SRM technology that would block out sunlight by introducing reflective particles into the stratosphere, by applying Karl Popper's concepts of piecemeal and utopian social engineering. To this end, we first briefly discuss the concept of the Anthropocene and the role of technology in this new epoch. We then introduce Popper's concepts of piecemeal and utopian social engineering and examine how SAI relates to these categories. We apply the resulting insights to the debate on SAI more generally, and reflect on our findings.

The Earth's climate is a permanently changing system. Although there are phases of relative stability that may last millions of years, it also occasionally undergoes rapid transitions into new states. A very recent addition to the list of factors that contribute to change in the Earth's climate system is humanity, which in its modern form has developed in the short, relatively stable geological epoch of the Holocene. Particularly during the past century, global population growth and natural resource exploitation have soared, and the increase of atmospheric greenhouse gas concentrations associated with these developments may lead to a rise in global mean temperatures of 4–6°C by around 2100 [*Van Vuuren et al*., 2011]. The current atmospheric concentration of the greenhouse gas CO_2 is now higher than at any time since about 3 million years ago [*Pearson and Palmer*, 2000; *Zeebe*, 2012]. The induced changes will continue for geological timescales, given the long residence time of CO_2 in the climate system [*Archer et al*., 2009]. As a consequence of this and other measurable global impacts of human activities that influence the Earth's future on geological time scales, geological societies are considering a formalization of the term "Anthropocene"

[*Crutzen and Stoermer*, 2000], delineating the epoch during which humanity has become a global forcing agent, as a unit on the Geological Time Scale [*Zalasiewicz et al*., 2010]. While we focus on climate change in this contribution, many other aspects of the environment are also influenced by humanity's impacts [*Rockström et al*., 2009].

As a result of the rapidly increasing impact of human activities on natural processes, the Anthropocene is expected to be characterized by significant changes to the baseline conditions against which contemporary societies have developed during the Holocene. If the current developmental paradigm, based on economic growth through extensive resource extraction, continues to persist, this would, in the face of a rapidly growing global population, dramatically accelerate global environmental degradation and thus erode the very foundations on which the current "developed" lifestyle is based. A number of academics [e.g., *Scheffran et al*., 2012] and political bodies have suggested that such an erosion of the foundations on which societies are based is a potential threat to international peace and security. (For example, UNSC, Statement by the President of the Security Council, 20 July 2011, S/PRST/2011/15; OSCE, Madrid Declaration on Environment and Security, 30 November 2007, MC.DOC/4/07.) However, frictions are likely to occur not only over the distribution of the costs that environmental degradation entails, but also over the means that societies draw upon to respond to it.

For climate change, response strategies have traditionally been distinguished as either belonging to mitigation (reducing greenhouse gas emissions) or adaptation (adapting to unavoidable climate change). In both of these categories, technological innovation plays an important role—for energy efficient production processes, better waste incineration plants, better heat insulation in buildings, the development of alternative energy sources, etc. These are all technological fixes that promise to better compensate for humanity's ever increasing consumption of natural resources—without affecting the basic pattern of production and consumption itself, even though resource diversion leads to losses in efficiency. However, increasing technological leverage over natural processes opens up the possibility to intervene at a more fundamental level, for example, by deliberately changing Earth's radiation balance to actively reduce global mean temperatures.

2. Technology in the Anthropocene

A key reason for both environmental degradation and the high levels of prosperity in many countries has been the extensive and to a large extent uncoordinated use of technologies. Especially, the large-scale extraction and use of fossil fuels, particularly for transport and electricity, has been a key driver for economic growth and prosperity as well as for the destruction of ecosystems and for climate change. Hence, the sustainable use of technologies is considered to be of critical importance for avoiding dangerous environmental degradation. Following this line of argument, it is frequently suggested that increased scientific-technical innovation will provide the means for increasing prosperity while reducing stress on ecosystems. Indeed, the idea of engineering has had a strong influence on how the concept of sustainability has actually been put into practice and can be traced back throughout the history of the sustainability discourse [e.g., Töpfer, 2013], while calls for fundamental changes in production processes and consumption patterns have little to show in terms of results. How can the role of technology and of increasing technological leverage over natural processes then be understood in the Anthropocene?

There are many different ways to approach this question. One road often taken by environmentalists is to denounce technological solutions to environmental problems as fast and cheap"techno-fixes," driven by a tremendous institutional and economic momentum, and based on an asserted habit of western culture of attempting to solve problems with technology by changing the circumstances, rather than addressing their root causes [*Borgmann*, 2012]. Others embrace technology and advocate planetary management [*Smil*, 2002]. In between these extremes there is a wide spectrum of more nuanced approaches, many of which see the need to draw on technology for solving problems, while also being aware of the problems the use of technology itself may create.

Recently, direct and intentional interventions into the climate system by technological means, generally referred to under the umbrella terms "geoengineering" or "climate engineering" [*Rickels et al*., 2011], have gained prominence in the debate on how to address climate change. These technologies are frequently clustered into two types of methods: those that attempt to intervene in the carbon cycle by removing

CO_2 from the atmosphere, and those that attempt to reduce the amount of solar radiation that reaches the Earth. For the latter, SAI, which involves the injection of reflective aerosol particles or particle precursors such as sulfur dioxide, has been suggested as a method that might have the potential to significantly reduce global mean temperatures on the short timescale of just a few years. Although this technology has not been developed yet and significant uncertainties about its technical feasibility remain, discussions about its socio-political implications have developed rapidly over the last decade.

In the remainder of this article, we shed light on this debate by showing that while several commentators have pointed out undemocratic and conflict-inducing aspects that an implementation of SAI might imply, it can also be seen as fitting very well with the established mode of technical-scientific problem solving that dominates current politics. In fact, this might very well be what fuels the controversy over SAI. From this perspective, SAI can be seen as a change-inhibiting project that prolongs an unsustainable and unjust status quo, or even intensifies existing inequalities and may hinder progress toward a decarbonization of the economy, which could in turn result in the necessity to maintain SAI to avoid a disastrous rapid warming if it were stopped. We thus argue that much of the current debate on SAI is driven not by considerations of whether the technology would "work" and at what price it would do so (meaning both economic costs and side effects, for example, on human health or costs resulting from adapting to changed weather patterns), but by value judgments about the desirability of specific forms of societal development. We conclude that this perspective, from which societal development is seen as a consequence of technological development, is based on a narrow understanding of the relationship between technology and politics, and that stronger attention should be paid to the social and political processes that underlie and guide the technology's use.

3. Reflecting Sunlight to Cool the Planet — Piecemeal or Utopian Social Engineering?

The terms piecemeal and utopian social engineering were coined by *Popper* [2011 (1945)] in his influential work "The Open Society and its Enemies." For Popper, piecemeal social engineering describes an approach that challenges the status quo only in small steps, without an ultimate aim in mind for societal development. Except for a very general principle of the minimization of harm, no fixed desirable final state of affairs is laid out. This form of social engineering is not only designed to avoid violent holistic social change, but is also intended to allow for continuous criticism aimed at early detection of errors along the way. For Popper, this reflects the method of trial and error underlying all kinds of problem solving behavior, including the scientific method. In contrast to this, utopian engineering aims at revolutionary change with the goal of achieving a predefined ideal state, based on assumptions of the capacity for omniscience and control. In his writings, Popper used this concept to criticize ideologies such as fascism and communism that attempted to create new societies by radically removing old structures and replacing them with new, designed ones — in the case of fascism and communism, with deadly force. Although revolutionary changes do not necessarily result in bloodshed, a utopian approach to societal development and transformation essentially implies a fundamental challenge to the status quo, deeply threatening established structures and interests.

Commentators have pointed out that SAI, along with some other climate engineering approaches, originates in utopian thinking [*Fleming*, 2010], is advocated by "Prometheans" [*Hamilton*, 2013], and is fundamentally undemocratic [*Szerszynski et al*., 2013]. Such criticism seems to suggest that implementing SAI as a response to rising mean temperatures would either necessitate or induce utopian social engineering.

For example, *Szerszynski et al*. [2013] describe SAI as an "inherently political" technology that is unfavorable to democracy, while favorable to political patterns driven by authoritarian elites and based on expert knowledge and centralized control. It seems to be, or so *Szerszynski et al*. [2013] argue, "strongly compatible with a centralized, autocratic, command-and-control world-governing structure" which would be "in tension with the current, broadly Westphalian, international system based on national self-determination" [*Szerszynski et al*., 2013, p. 2812]. ("Westphalian order" refers to the system of sovereign nation states that emerged after the Peace of Westphalia in 1648, which has strongly shaped international politics. Whether the Westphalian order is still a useful concept to capture current dynamics in international politics is a contested subject, based on the increasing importance of

supra- and subnational entities and non-state actors such as large corporations and nongovernmental organizations.) This suggests that SAI has the potential to overthrow the existing structure of the international system, a development that, while not entirely consistent with Popper's use of the term, could be considered tantamount to utopian social engineering, in the sense that it radically challenges the status quo.

However, a closer look at SAI in light of Popper's categories can open up an interesting and insightful perspective on the matter [see also *Dickel*, 2013]. From this perspective, SAI might in fact not necessitate revolutionary social change to the existing social order, but could very well work to hinder or even prevent such radical change. There are two lines of argument that support this interpretation.

The first line of argumentation is related to what in the debate on SAI, and climate engineering more generally, has been referred to as a "moral hazard" [*Keith*, 2000; *Hale*, 2012], a term originating in insurance theory [*Arrow*, 1963]. These arguments refer to the possibility that discussing, researching, and implementing SAI may reduce the motivation to pursue mitigation efforts. This is because such activities may divert attention, efforts, and incentives from the challenge of decreasing greenhouse gas emissions, increase risk-prone behavior (i.e., not reducing emissions), encourage political inaction and maintenance of the status quo, or support a "rational" cost-benefit-based delay of emission reduction. SAI, it is feared, will hinder a radical social transformation toward a carbon-free economy.

The second line of argumentation is directly related to the political implications that *Szerszynski et al*. [2013] fear. While it is in no way clear at this point in time how SAI might impact international politics, it appears as if the pathway that *Szerszynski et al*. [2013] outline, in which the state-based international system of Westphalian order is threatened by more centralized forms of organization, is not all that far removed from the situation we face already. While we are certainly not currently experiencing a "command-and-control world-governing structure," international authority in the form of centralized decision-making processes in international institutions has been steadily increasing over the last decades. This is mirrored by the increasing contestation of the competencies these institutions have accumulated [*Zürn et al*., 2012]. It appears that the centralized, global structures that are currently in place could be capable of accommodating decision making on SAI without any revolutionary change. While SAI could provide a rationale for further shifts in authority from the national to the international level, it appears likely that this would occur in the form of piecemeal social engineering, rather than utopian social engineering.

In addition, in such institutions of global governance—to use a more popular term—decision making is heavily influenced by experts and technical-scientific world views. SAI, as a technical-scientific response to climate change, could turn out to be just another topic for negotiation in these settings. This of course does not mean that the outcomes of such negotiations would necessarily be desirable ones. However, it is unlikely that new institutions with huge overarching competencies would need to be created in order to enable discussions of SAI at the international political level, rather the current system of international institutions that we have in place is likely to be already sufficient.

Accordingly, while the fears that are outlined by *Szerszynski et al*. [2013] might be well founded, it would not necessarily take utopian social engineering to get us there. Rather, for both the global economy and international political order, it appears that the fears toward SAI do not only originate in the changes that it would bring about in the respective arenas, but also in what it would serve to preserve—a status quo that is perceived as unjust and environmentally unsustainable.

4. Conclusion

We have argued that the heated debate on the social and political consequences of SAI is to a large extent fueled by the fear that this technology would prolong or even preserve an undesirable status quo. This is in contrast, but not necessarily in contradiction, to other commentators who frame their criticism of SAI in the terms of concerns about radical change, for example, with respect to the centralization of authority it would require and the fossil fuel use it would encourage. However, our analysis suggests that within the existing economic and political order, none of the above (centralization of authority and increasing fossil fuel use) appear to necessitate radical changes to the status quo.

Taking a step back, it becomes clear that SAI might in fact fit quite well within the current political and economic structures. But is this even the right question to ask—whether SAI will change or preserve the status quo? This assumes that technologies have clear-cut political consequences that can be readily identified by examining the properties of a given technology. While widespread, this perspective hides from view that decisions about technological development and use, as well as decisions about societal development, are, in fact, *decisions*, meaning that they are open to contestation and resistance, and to active shaping through participation.

From this more nuanced perspective, the normative and political evaluation of SAI depends on how it would be used, if feasible and developed, and how such decisions are made. Would it be used as a stopgap measure to buy time for a societal transformation to a carbon-free economy, shaving off the worst effects of climate change along the way? Or as a substitute for this transformation, allowing for business as usual to continue? Or as an insurance policy against catastrophic climate change? Would decision making be participatory and inclusive, or restricted to a small elite? Would the interests of future generations be taken into account?

Humanity's ability to willfully influence processes that are fundamental to life on earth, from the molecular to the global systems level, is increasing rapidly. Decisions on how to further develop and use this capability will have far-reaching effects both spatially and temporally. The current debate on SAI might provide an outlook on how societies will grapple with the complex set of questions that emerges with the ability to fundamentally intervene in natural processes on a global scale in the Anthropocene, and how this interacts with social and political order. However, it also demonstrates the importance of emphasizing the political nature of technologies—not in the sense that they either change or reproduce the status quo as a political consequence of their technological properties, but rather that their development and use is subject to conscious decision making that can be contested and influenced.

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