Policy Brief

Environment Outlooks

May 2016

Combating Climate Change with Geoengineering

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Summary

Mitigation and adaptation are undeniably the two most appropriate responses to anthropogenic climate change. However, even with maximal mitigation and adaptation efforts, significant residual harm to both human and natural systems from climate change is inevitable. This harm that will result despite our best mitigation and adaptation efforts is referred to within the United Nations Framework Convention on Climate Change (UNFCCC) as loss and damage,[1] *and is expected to have disproportionate impacts on developing and least developed states—along with vulnerable populations within all states.*[1]

Given that loss and damage will occur despite substantial mitigation and adaptation, some scientists have begun researching the possibility of engineering the climate so as to minimize the forecasted residual harm as much as possible. Defined as the "deliberate, large-scale manipulation of the planetary environment in order to counteract anthropogenic climate change," [1] *geoengineering—or climate engineering—is an umbrella term, grouping a wide array of proposals that are generally grouped into two categories: Carbon Dioxide Removal (CDR); and Solar Radiation Management (SRM).*[1]

Solar Radiation Management proposals aim to reflect some percentage of incoming light and heat from the sun, thus reducing the increase in average global temperatures. One of the most widely discussed of these proposals, and the focus of this policy brief, is that of Stratospheric Aerosol Injection (SAI). By releasing aerosols into the stratosphere, we could create a kind of sunshade for the planet that could potentially allay further temperature increases. While being very cheap, effective, and nearly ready to deploy, the proposal has a number of empirical and ethical concerns that remain under-investigated. More research is needed in order to adequately assess the exact risks and benefits associated with SAI.

Policy Recommendations

The global community should continue mitigation and adaptation efforts, and do so with much greater commitment than has been exhibited to date. Yet given that mitigation and adaptation alone cannot alleviate all climatic harms, research into climate engineering—specifically Stratospheric Aerosol Injection—should continue with legitimate oversight and regulation in place.

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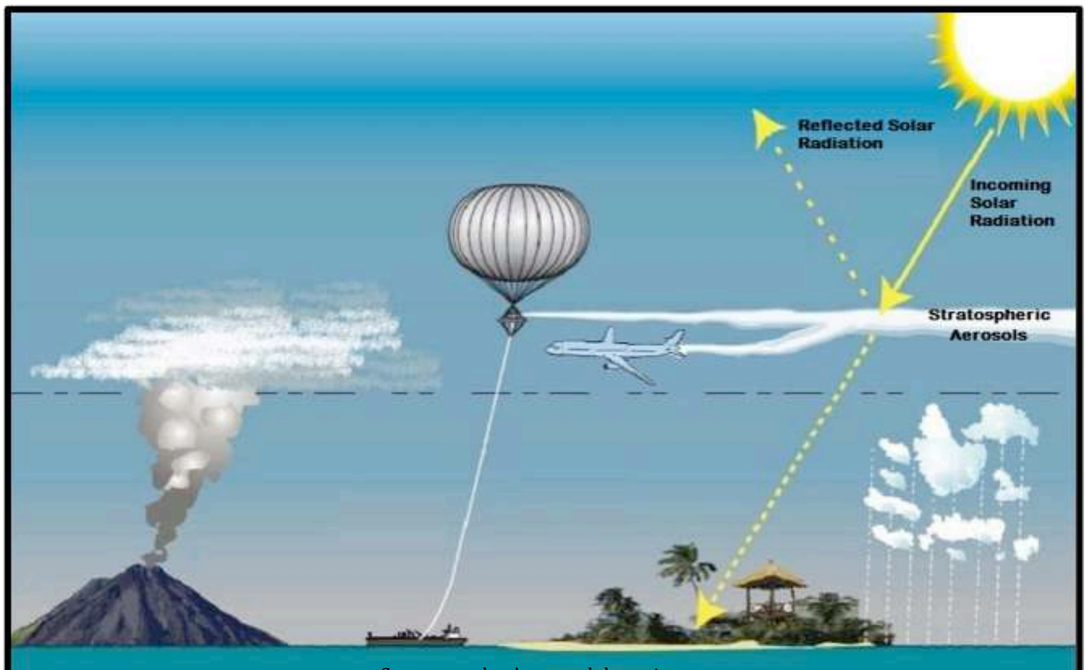
I. Introduction

As previously mentioned, Stratospheric Aerosol Injection is a kind of Solar Radiation Management. The main idea behind the proposal, as its name implies, is to inject aerosols into the stratosphere. These aerosols would create a semi-permeable layer capable of shielding the planet from some of the incoming solar radiation. Of course, the less radiation that makes it to the earth's surface, the less radiation there is to be trapped by the greenhouse effect. This reduction in the increase of average surface temperature that is caused by global warming will have positive effects on human and natural systems. Given that the negative effects of unchecked climate change stand to fall most heavily on the least developed and developing countries, along with poorer populations within developed countries, any chance at alleviating these negative effects deserves consideration.

There are a number of different delivery systems currently being discussed in order to release the aerosols in the stratosphere. For instance, we could use military-grade artillery guns or weather balloons outfitted with long hoses that would reach back down to the earth's surface. Perhaps the most popular and one of the most cost-effective of these methods involves the use of regular business jets. A Boeing 747 or fleet of similar aircraft could continually deploy 1 Mt of aerosols at the required altitude, enough to offset at least half of the expected temperature increase due to anthropogenic global warming.[i]

Along with the different delivery systems, there are also various kinds of aerosols that could be used. The most viable option at the moment is that sulfate aerosols, either sulfur dioxide (SO_2) or hydrogen sulfide (H_2S). One of the primary advantages to using sulfate aerosols is our understanding of how they work. In 1991, Mount Pinatubo released somewhere between 10-20 million tons of sulfur into the atmosphere that resulted in an average global cooling of 0.5°C for the year.[ii] The injection of sulfate aerosols into the stratosphere would mimic this natural volcanic effect.

Perhaps the two greatest merits of Stratospheric Aerosol Injection are its rapid efficacy and its comparative cost. First, once introduced into the stratosphere, the sulfate aerosols would start producing the desired cooling effect within weeks. In comparison, emission mitigation will only have a cooling effect across a time span of decades or centuries due to the inertia of the climate system. This near immediate efficacy is a significant benefit of the proposal. Second, the annual cost of releasing the aforementioned 1 Mt of sulfate aerosols into the stratosphere with retrofitted business jets would be roughly 1 billion USD.[iii] As has been noted in the Intergovernmental Panel on Climate Change's Fourth Assessment Report, the costs associated with annual climate damages or with emissions mitigation is estimated to be 200 billion USD to 2 trillion USD per year.[iv]



Source: author's own elaboration

Thus, SAI is comparatively cheap with respect to both the cost of mitigation and the costs of expected climate damages. However, it should be stressed that while SAI is comparatively cheap, it is not by any means a perfect substitute for mitigation.[v]

II. Empirical Concerns

There are a number of technological and empirical concerns related to the deployment of SAI. Three of the most pressing concerns highlight the fact that this proposal is not a perfect substitute for mitigation and should not be conceived of as one.

Continued Acidification of the Oceans

There are many different troubling implications associated with climate change such as increased average global surface temperatures, sea-level rise, and ocean acidification. While stratospheric aerosol injection can moderate increases in temperature and sea levels, it will do nothing to address the problem of ocean acidification. The pH balance of the ocean is being affected by the increased concentration of carbon dioxide in the atmosphere. Insofar as SAI will not affect the concentration of carbon dioxide, it will not halt or reduce the acidification of our oceans. However, this should not be seen as a reason not to push forward with research into the technology. Rather, it should be seen as yet another reason to continue with strong mitigation efforts. SAI will not address all of the negative aspects of climate change. But to the extent that it can reduce the increase of average surface temperatures and sea-level rise, it nonetheless deserves our attention.

Disruption of Precipitation Patterns

Another worry of injecting enough sulfur into the atmosphere to counteract all anthropogenic warming is that it could cause serious disruption to the Asian and African monsoons—an effect that has the potential to catastrophically impact the food security of billions of people.[vi] If this were an inherent feature of the technology, it would provide us with a good reason to abandon it is a potential policy avenue. But deploying SAI is not analogous to flipping a light switch that is either 100% on or 100% off. Rather, SAI can be initiated and then slowly dialed up. We could start by injecting enough sulfur to counteract only 5% of anthropogenic warming, and then slowly increase efforts to a final point at which 50% of all anthropogenic warming is offset. When used for the offsetting of only *half* of all anthropogenic warming, the impact on regional precipitation, and thus food security, is negligible and even positive in some computer models.[vii] Still, more research is needed in order to better predict effects on regional climates.

Ozone Depletion

A third worry associated with SAI is that of ozone depletion. In the final quarter of the 20th century, it became evident that chlorofluorocarbons (CFCs) and other substances were causing serious harm to our planet's atmosphere, specifically the stratospheric layer of ozone near the poles.[viii] The 1985 Vienna Convention and subsequent 1987 Montreal Protocol limited the production and use of these dangerous substances. Atmospheric ozone has been replenishing over the past three decades, and a complete recovery is expected in 50 years or so.[ix] One negative consequence of injecting sulfur into the stratosphere is that it will be a hindrance to atmospheric ozone recovery. This is because sulfuric aerosols will hasten the breakdown of the CFCs already in the atmosphere.[x] There are three reasons we should, despite the risk of ozone depletion, continue research into SAI. First, due to the complicated atmospheric chemistry involved, we do not know exactly how much any given quantity of sulfates will hinder ozone recovery. With more research we can get a better idea of exactly what the risk amounts to. Second, the risk SAI poses to ozone recovery will depend upon *when* the technology is used. If SAI were to be deployed in the second half of the 21st century after the control measures within the Montreal Protocol have had enough time to nearly eliminate the presence of CFCs in the atmosphere, then the sulfates would have much less of an effect on ozone. Finally, this worry about ozone is spurring research into so-called "smart particles" that could replace sulfate aerosols, retaining their beneficial properties and avoiding many of their downfalls including ozone depletion.

III. Ethical and Political Concerns

There are many technological and logistical problems that need to be worked out before any potential deployment of SAI. Though, as noted by the Royal Society, perhaps the biggest obstacles facing such a proposal are ethical and political issues.

Moral Hazard

One reason the subject of geoengineering in general is somewhat taboo is the concern about it representing a moral hazard. A "moral hazard" characterizes how secondary plans can embolden individuals to take on risks that they otherwise would not have assumed without the insurance of the secondary plan. Some worry that if we have geoengineering as a backup plan, it will weaken our resolve to engage in mitigation and adaptation. The moral hazard concern represents a serious worry to geoengineering research, but two considerations should be noted. The first is that there is little empirical evidence to show that such a hazard exists. That is, it isn't clear that research into geoengineering would actually weaken our resolve to mitigate. Secondly, even if research does weaken our resolve to mitigate and adapt, we will want to know if it has a negative *net* effect. Without evidence that such a moral hazard exists, and without any data to show that the hazard would be deleterious all-things-considered, the moral hazard worry itself should not stand in the way of research.

Respect for Nature

Another hurdle for SAI is the thought that this kind of engineering of the climate shows a disrespect for nature. Intentionally meddling in the climate system, it is argued, fails to show nature the proper respect it is due. It seems right to acknowledge that intentionally manipulating the climate is, perhaps, failing to give adequate respect to nature. But it's unclear how refraining from geoengineering and allowing anthropogenic climate change to bring about disaster to natural ecosystems and vulnerable human communities is not subject to the same charge. If what we value about nature is biodiversity and healthy ecosystems, deploying SAI in order to limit harm these ecosystems and the diverse species that comprise them may be one way to respect nature in the face of unchecked anthropogenic climate change.

Path-Dependency / Lock-In

Whether or not SAI will succeed in reducing climatic harms and do so without overwhelming negative side-effects is uncertain at this point in time, which is why many advocate for research. Yet some worry that even beginning research starts us down a path towards the inexorable deployment of the technology, regardless of whether research proves it safe or not. The worry about path-dependency or lock-in is serious, and needs to be addressed with legitimate regulation and oversight in order to make sure that the technology is not deployed prematurely. This regulation could, for instance, incorporate "stage gates" in which regulator sign-off would be required to move from computer models to laboratory experiments, from laboratory experiments to small field trials, and from small field trials to larger atmospheric tests.[xi]

Legitimate Governance

Legitimate governance and regulation would go a good way towards allaying some of the worries associated with SAI. But, as we have seen when it comes to regulating greenhouse gases, legitimate governance can prove challenging. In order for a geoengineering regulatory institution to enjoy political legitimacy, it would have to have broad participation and procedural inclusion, transparent and accountable decision processes, and be guided by norms of justice and fairness.

IV. Conclusion

It's clear that our primary response to climate change should lie in mitigation and adaptation efforts. But it is also clear that mitigation and adaptation alone will not be enough. Geoengineering proposals, especially SAI, can be useful complements (but not substitutes) to mitigation and adaptation efforts and can meaningfully contribute to assuaging the climate-related harms that are to disrupt natural ecosystems and the development of vulnerable human populations. Research into these technologies ought to go forward, with legitimate regulation and oversight in place.

[i] David Keith & Douglas MacMartin, “A Temporary, Moderate and Responsive Scenario for Solar Geoengineering,” *Nature Climate Change* 5:3 (February 16, 2015): 201–6.
[ii] Mike Hulme, *Can Science Fix Climate Change?* (Cambridge, MA: Polity Press, 2014): 44-45.
[iii] David Keith & Douglas MacMartin, “A Temporary, Moderate and Responsive Scenario for Solar Geoengineering,” *Nature Climate Change* 5:3 (February 16, 2015): 201–6.
[iv] Barker T et al 2007 Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Geneva: IPCC) Table SPM4.
[v] There are a number of reasons why SAI is not a perfect substitute for mitigation. Three of these reasons will be discussed in the following section.
[vi] Alan Robock, “20 Reasons Why Geoengineering May Be a Bad Idea,” Bulletin of the Atomic Scientists 64, no. 2 (May 1, 2008): 14–18.
[vii] David Keith, *A Case for Climate Engineering* (Boston: MIT Press, 2014) pp. 52-60.
[viii] Scott Barrett, Environment and Statecraft (Oxford University Press, 2005), p. 223.
[ix] National Oceanic and Atmospheric Association, http://www.ozonelayer.noaa.gov/science/basics.htm (accessed April 29, 2016).
[x] Paul J. Crutzen, “Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?,” Climatic Change 77, no. 3–4 (September 1, 2006): 211–20.
[xi] Rayner, Steve et al., “The Oxford Principles,” *Climatic Change* 121, no. 3 (December 2013): 499–512.