Governing the Sun: Stratospheric Aerosol Injection and Challenges for Global Governance

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Introduction

The IPCC's 6th Assessment Report projects that the planet will warm anywhere from 1.5°C to 5°C relative to preindustrial temperatures by 2100[1]. Already, we are seeing impacts of this warming that are dramatic and severe. To quickly counteract this trend, some propose Solar Radiation Modification (SRM) techniques that would "dim the sun" and lower global surface temperatures. Among the most widely discussed SRM strategy is stratospheric aerosol injection (SAI), which would release particles into the stratosphere to reflect shortwave radiation away from the earth's surface. While technically sound and cost-effective, SAI is not well-understood and could have devastating impacts on certain regions of the world. The following report gives a brief overview of SAI technology, discusses the challenges it presents, and gives recommendations for global governance of SAI.

How does SAI work?

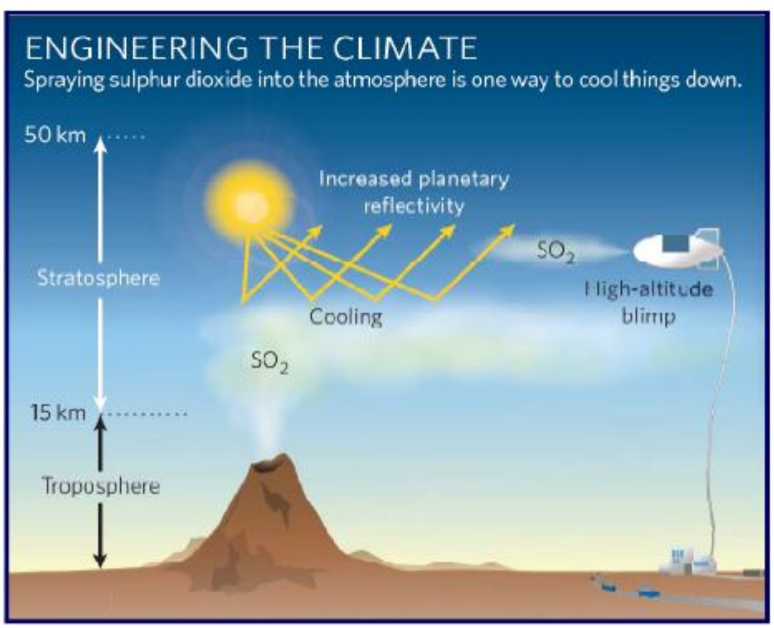

Figure 1: Simple sketch of how both natural and anthropogenic SAI result in higher planetary albedo and lower surface temperatures[2].

Natural SAI | Geoengineering with SAI is inspired by volcanic eruptions, which introduce massive amounts of sulfur dioxide[*] into the atmosphere and are associated with temporary drops in surface temperature. In 1991, Mt. Pinatubo erupted In the Philippines, naturally injecting 15 million tons of sulfur dioxide gas into the atmosphere. This resulted in a 0.6°C average reduction in global temperature over the next two years[3].

Anthropogenic SAI | To mimic this process with SAI, aircrafts would manually inject large amounts of sulfur dioxide gas into the atmosphere (Figure 1). These gases then photochemically convert to reflective sulfate aerosols that scatter incoming shortwave radiation, preventing it from reaching and warming the earth's surface[4].

Efficacy | As observed in the period following the Mt. Pinatubo eruption, cooling effects of aerosol injection last for about two years. In addition to observed natural cooling, climate models have projected that SAI would effectively lower global mean surface temperatures and moderate key climate hazards brought on by a warming planet[5].

Cost | At an estimated yearly price of $18 billion per degree of warming avoided, SAI is incredibly cost-effective relative to other climate solutions[6].

Concerns

While SAI may hold promise in addressing rising temperatures, it remains highly controversial and is still largely unpopular in prominent scientific communities[7]. Some common criticisms of SAI are as follows:

- While SAI would reduce global surface temperature, it does nothing to address non-temperature impacts of GHG emissions. If SRM is used in place of mitigation, the elevated atmospheric CO_2 concentrations will continue to **acidify the world's oceans**[8].

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[*] SAI can also be accomplished with other aerosols such as nitric oxides, black carbon, and engineered nanoparticles. However, sulfur dioxide is far and away the most widely discussed and realistic option.

- Through interactions with cloud-forming processes, increased stratospheric aerosols alter precipitation patterns, resulting in an overall **decrease in global precipitation**[9].
- Excess sulfur dioxide reacts with water and oxygen in the atmosphere to form sulfuric acid, lowering the pH of atmospheric water vapor and resulting in **acid rain**.
- **Public health effects** of long term increased exposure to sulfur dioxide and other aerosols are not well understood and could be harmful[10].
- Even a global deployment of SAI would not impact all regions of the earth equally. Given its tendency to alter precipitation patterns, SAI could cause **increased drought and food shortages** in vulnerable areas[11].
- Stratospheric aerosol chemistry is not well understood, leading to **high uncertainties in projections**. Climate models often reduce values of shortwave energy inputs rather than model all of aerosols' diverse interactions, resulting in biased and limited projections[12].

Discussion – Global Governance

SAI poses incredible challenges for governance. First, atmospheric gases do not respect geopolitical boundaries. Any large-scale aerosol injection would have effects well beyond the borders of any individual country that decided to deploy it, and any implementation on the scale required to meaningfully lower global surface temperature would alter the climate of every nation on earth. At a yearly price of $18 billion per degree of warming, it is unlikely that private actors would have the means and incentives to finance global-scale SAI[13]. Thus, SAI would need to be deployed by state actors and governments with centralized resources and decision-making capabilities.

The world's largest economies (U.S., China, UK, Russia) tend to exert outsized influence on global geopolitics[14], and any one of these nations could unilaterally finance an SAI deployment that would lower global surface temperature by several degrees C°. However, given the disparate regional impacts and concerns, a just implementation of SAI requires collaboration with all nations on earth. Moreover, those who traditionally have had little influence on global decision-making are low-income nations that are most vulnerable to climate change's pernicious effects[15]. Many of these same nations are also at the highest risk of harmful impacts of SAI, through altered precipitation patterns and acid rain. Thus, it is crucially important that vulnerable, low-income nations have a seat at the table when discussing SAI, as they have the most to either lose or gain from its deployment. However, as we've seen with recent failures of international climate cooperation at the COP26 Summit[16], the global governmental order lacks effective mechanisms to implement global environmental policy. There is no international body that exerts real enforcement authority over all nations on earth, and as such, no way to ensure democratic, equitable decision-making related to SAI deployment.

Moreover, SAI is one of the few solutions to global temperature rise that does not disrupt the global economic order through aggressive mitigation measures (such as a Green New Deal or an immediate cessation of fossil fuel use would). Unsurprisingly then, studies have shown that SAI research is primarily funded by wealthy, mostly white philanthropists, and ivy-league academics in the global north[17]. These actors enjoy rarefied status in today's social hierarchies and stand to lose the most from the reshaping of the global economy that would come from radical climate mitigation. However, if SAI is used in place of mitigation strategies that address the root cause of global warming, there will be less incentive to reduce emissions and transition to renewable energy sources. Without this mitigation, non-temperature effects of emissions like ocean acidification, acid rain, and public health impacts will only worsen.

Recommendations

Geongineering the earth's climate with SAI remains a technically feasible, cost-effective way to reduce rising global temperatures and potentially protect against many of climate change's worst impacts. However, it fails to address the root causes of global warming. Its impacts on human populations are not well understood and potentially devastating. Moreover, given the global geopolitical power structure, there is no method for equitably reaching a decision on deployment or fairly and effectively governing the technology after it has been deployed. Thus, I propose that the international global order institutes a non-use agreement for SAI technology that puts a moratorium on all deployment, research, testing, and international organizational support (*Figure 2*)[18]. This is the only way to ensure that earth's climate isn't irreversibly geoengineered without the consent of all the world's people.

Figure 2: Proposed criteria for an SRM global non-use agreement[18].

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