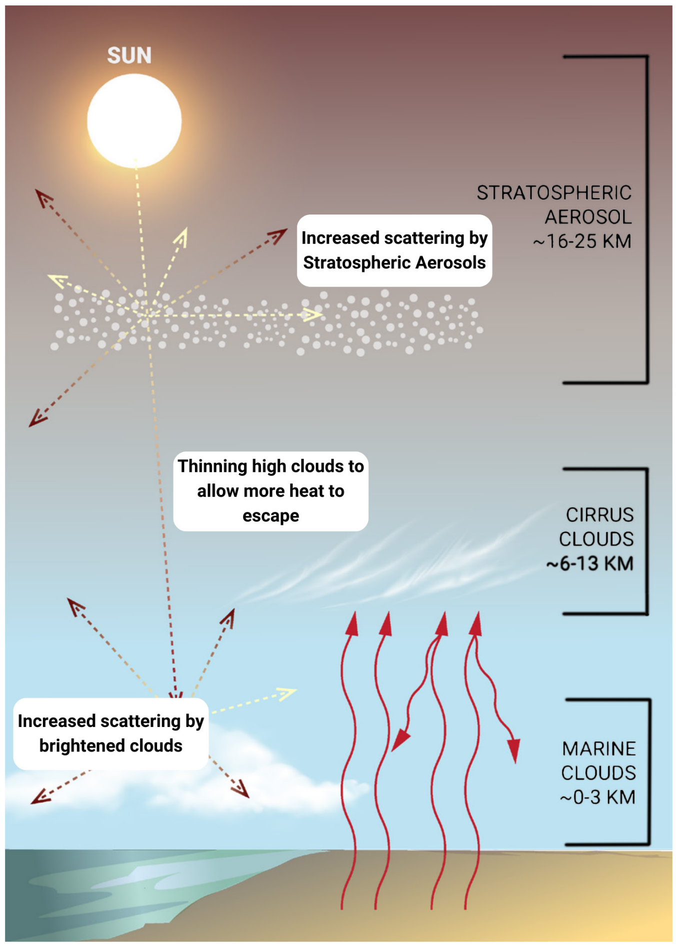
BRIEF OF THE SCIENTIFIC ADVISORY BOARD ON:

SOLAR RADIATION MODIFICATION

WHAT IS SOLAR RADIATION MODIFICATION

Solar Radiation Modification (SRM)[1] – also called "solar geoengineering" – is an umbrella term for technologies aimed at reducing global warming by increasing reflection of the sun's energy back to outer space. It includes cirrus cloud thinning (allowing more sunlight to escape out from the atmosphere), ground- or ocean/ice-surface-based Albedo modification (creating more reflective ground surfaces), marine cloud brightening, stratospheric aerosol injection, and the largely theoretical proposals to place mirrors or shades in outer space.[2]



SRM does not reduce the amount of greenhouse gases in the atmosphere and would not address their other impacts (e.g. ocean acidification, biodiversity loss, air pollution). To maintain cooling effects, it would need to be continuously deployed at scale. As such, SRM is generally considered a temporary, supplementary or emergency effort to the primary objectives of the Paris Agreement.[3] But as global temperatures rise above the 1.5-degree temperature goal, planetary cooling technologies like SRM may increasingly become a serious consideration.

One of the most important and studied SRM techniques is **Stratospheric Aerosol Injection (SAI),** the release of aerosols or precursor gases at an altitude of roughly 25 kilometers above the Earth's surface. If deployed continuously at roughly the volume of a large volcanic eruption every year, SAI theoretically could generate up to 1 degree of global cooling; and some estimates suggest that larger-scale SAI could produce a cooling effect of up to 5 degrees.[4]

WHY IT MATTERS:

The technologies for altering the reflective capacities of the Earth's surface and atmosphere could relatively quickly reduce temperature increase and cool the planet. However, they could also generate a wide range of unintended consequences including uneven cooling, further climate variability, disruptions to the lower and middle stratosphere, acid rain, and could reduce incentives to mitigate global greenhouse gas emissions.

WHAT ARE THE LATEST DEVELOPMENTS?

Indoor/computer modeling of SRM has been ongoing for more than 50 years, though the past ten years have witnessed an increase in SAI modeling.[5] Outdoor tests have proven more controversial and have not yet been carried out at large scale. Proposed SAI tests in the UK and Sweden were halted in 2012 over legal challenges and objections by local communities.[6] A 2022 test of a balloon technology designed to carry sulfur into the high atmosphere was conducted in the UK despite serious concerns by scientists.[7] In March 2024, Harvard University cancelled its planned outdoor testing of SAI following strong public pressure.[8]

Large-scale deployment of SAI is expected to be technologically feasible in under ten years, with some estimates suggesting a shorter timeline.[9] This could generate significant impacts for relatively low cost – some experts have suggested that 1 degree of cooling could be achieved for as little as $20 billion.[10] Within the US, this potential to achieve quick, cheap cooling impacts has contributed to major increases in private investments in research and testing.[11] Small-scale outdoor tests of SAI were conducted in the US last year, and more are expected in 2025.[12]

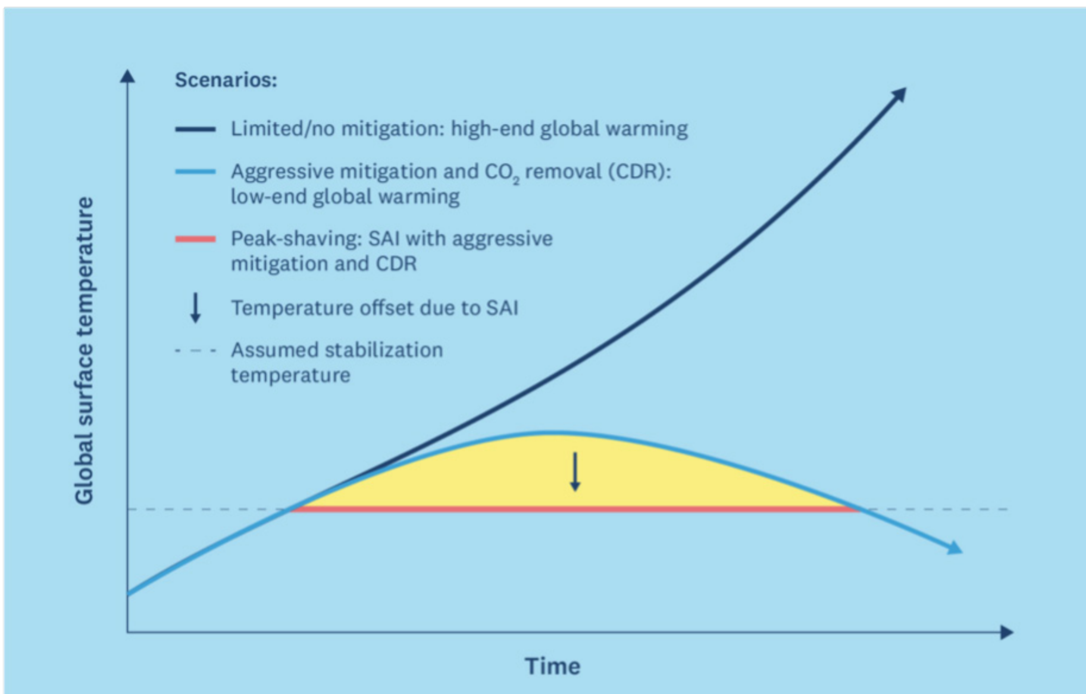


Figure 1) Potential for SRM to Provide Global Temperature Reduction

WHAT ARE THE RISKS OF STRATOSPHERIC AEROSOL INJECTION?

Empirical tests of SAI are extremely difficult, as the full range of effects can be evaluated only through some form of outdoor deployment.[13] Computer modeling of the potential effects of SAI are unlikely to produce accurate predictions given the complexity of interactions of the atmosphere with the Earth's systems. With those limitations in mind, some of the main risks posed by SAI are described here.

Current modeling suggests that even a uniform deployment of aerosols across the atmosphere would produce **uneven global effects**, just as global warming does today.[14] Some scenarios would see dramatic cooling in some regions and heating in others, including around the highly sensitive Antarctic.[15] Uneven effects could cause changes in tropical monsoons, seasonal hurricanes, and suggested shifts in the major systems of climate variability (e.g. El Niño, or the polar vortex).[16] Massive flooding in northern Europe and extreme drought in southern Europe are predicted in other models.[17]

The uneven distribution of effects globally could give rise to significant **international tensions**. For example, an SAI deployment could lower temperatures in one region but cause massive flooding or drought in another.[18] The lack of an international framework or applicable laws to manage such transboundary effects, and the difficulty of attributing harm caused by atmospheric changes, present risks of inter-state escalation.[19]

Large-scale SAI could have a **detrimental impact on the atmosphere.** The use of sulfate particles (only one of the options being considered) could produce acid rain, changes in the chemistry of the atmosphere, and/or depletion of the ozone layer.[20] These environmental impacts mean SAI may contribute to greater greenhouse gas retention in the atmosphere.[21] Other outcomes of placing large quantities of sulfur or other aerosols in the atmosphere are difficult to assess but potentially severe.

To maintain its cooling effect, SAI would require a continuous process of injecting particles into the stratosphere. As soon as deployment ends, the particles would begin to settle out of the stratosphere and the accumulated effects of greenhouse gas emissions might accelerate dramatically. Referred to as **"termination shock,"** the impacts of a sudden stoppage of SAI could include the abrupt loss of thousands of species, catastrophic weather patterns, and potentially large-scale loss of human life.[22]

SRM could present a significant **moral hazard** as well. By investing in a technology that only temporarily masks the effects of carbon emissions, financial and political incentives to invest reaching net zero could be diminished.[23] However, the risks of our current trajectory of global warming are also alarming: the IPCC has predicted enormous declines in human and environmental well-being as we move from 1.5 to 2.0 degrees of warming.[24]

Facing highly uncertain global outcomes and potentially devastating impacts on human well-being and the environment, a group of scientists and countries have called for a **moratorium on SRM** testing and deployment until the risks have been better understood.[25] In contrast, some scientists and organizations have argued that greater testing of SRM is needed to understand the full range of risks.[26] These positions reflect a chicken/egg challenge of SRM: some form of testing may be required to understand the risks, but large-scale outdoor testing could generate some of the unintended consequences described above.

WHY SRM MATTERS FOR THE UN

No specific international legal frameworks exist to govern large-scale deployments of SRM.[27] A number of multilateral agreements do contain provisions applicable to SRM (including mention of its impacts on ocean fertilization in the Convention for Biological Diversity London Protocol), but none target the global impacts of the technology itself.[28] Reflecting this shortcoming, a recent UN General Assembly resolution welcomed legal guidance on addressing the risks posed by SRM.[29] At the 2024 UN Environmental Assembly, a proposed resolution calling for more research into SRM failed to achieve consensus, though received significant support.[30]

The lack of domestic regulation in many parts of the world means that outdoor testing will be difficult to regulate via national systems, nor are there well-recognized processes to establish liability for any harms caused by testing or deployment. An IPCC report from 2018 predicted a high likelihood of unilateral deployment of SRM with the potential for major international disruptions.[31] However, apart from a 2023 incident where a US start-up company reportedly released sulfur particles over Mexico (resulting in Mexico banning solar geoengineering), such disruptions have not yet taken place.[32]

The combination of inadequate international legal provisions, medium to high probability of large-scale testing soon, and existing treaty-based obligations on climate mitigation makes SRM a topic of immediate concern for the UN. In this context, the Board notes that UNEP and WMO are hosting a consultative workshop on 19-20 May 2025 to provide an update on the current science of SRM and the status of research with member states and other stakeholders. It will also assess critical knowledge gaps and particularly the near-term risks and a preliminary mapping of key concerns on SRM.

CONSIDERATIONS

The question of how to grow our scientific knowledge of the risks of SRM while also developing governance frameworks is a complex one without consensus in the scientific community.[33] Some key considerations for the UN system in this context include:

- **The precautionary principle/approach.** Contained in many international agreements, the precautionary approach broadly requires actions to prevent or minimize environmental harm where there are serious threats of irreversible damage. Specifically, the precautionary principle requires that scientific uncertainty shall not be used as a reason to postpone or avoid preventative actions.[34] Given significant uncertainty about the possible regional and global effects of SRM, the Board notes that a growing number of scientists, organizations and states have called for some form of "pause," "moratorium" or "non-use agreement" on SRM.[35] Other scientists have stressed the need for further scientific assessments that might require further outdoor testing.

- **A scientifically-informed forum to advance consensus on SRM governance.** Some scientists and experts have proposed a dedicated forum that brings together scientific, political, and other stakeholders. Such a forum could involve the use of existing forums and institutions[36]. From a scientific and technological standpoint, such a forum could help build consensus around principles, standards, and eventually regulations. It could help build up technological capacities to monitor atmospheric testing, improve transparency around research funding globally, and build consensus on common standards for responsible research.[37]

- **A comprehensive scientific SRM review process.** The Board notes the many recommendations, including by UNEP and the IPCC, for a globally inclusive, transparent and equitable scientific review process for SRM.[39] Such an assessment would enable a scientifically-informed assessment of the risk trade-offs between climate altering technologies and those of continued global warming at current rates.[40] Such a review could also draw on a wide range of perspectives, including views from global South, developing regions, and Indigenous communities.[41]

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