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Solar Radiation Management

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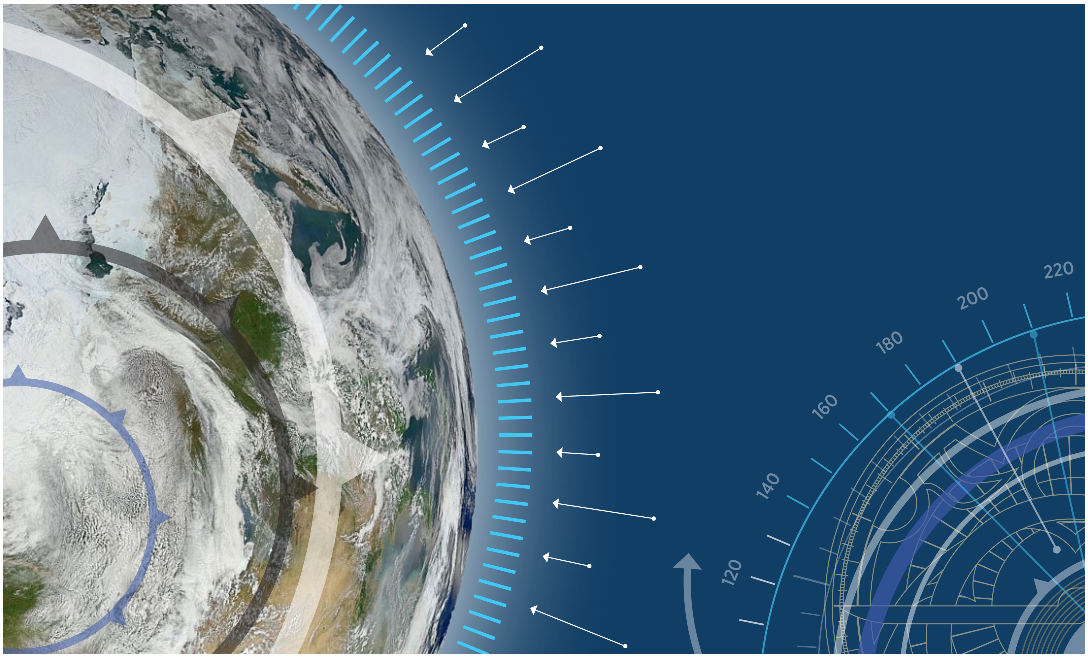
Despite extensive efforts, greenhouse gases continue to be emitted in vast amounts, with potentially devastating consequences around the world. This is why targeted interventions in the climate system, known collectively as 'climate engineering', are receiving increased attention. Proposed approaches are often divided into two groups: those intended to remove carbon dioxide from the atmosphere and those intended to reduce the amount of solar energy that reaches the Earth's surface or is trapped in the atmosphere. There are some similarities between the two classes of activities, but they often raise different physical, political, and governance concerns. This series provides an introduction to each set of approaches.



What is solar radiation management?

Technologies for solar radiation management (SRM) are being developed in the hope that increasing the reflection of sunlight back to space may reduce some of the risks of climate change that cannot be addressed by the other main policy options: mitigation, adaptation, and carbon dioxide removal. One prominent proposal involves spraying reflective aerosol particles into the upper atmosphere. Another would involve spraying seawater into the air directly above the ocean, which would then be lofted into low-lying clouds, making them more reflective. Other techniques have been proposed, such as brightening the land or sea surface or putting reflectors into space, but these are receiving less attention from scientists due to concerns over effectiveness, feasibility, or both. Finally, a new and related technique would enhance the transmission of terrestrial radiation upwards through the atmosphere by modifying cirrus cloud properties (rather than removing greenhouse gases). While the latter is not strictly solar radiation management, this fact sheet refers to all these approaches.

Why is it important to discuss solar radiation management?

Intentionally intervening into the climate system is an endeavour that is by definition global in scope. Climate engineering may have significant positive and negative impacts on populations and ecosystems, may require a reshaping of interstate relations and international institutions, and may be seen differently by different social groups. All this makes an inclusive and critical societal debate vital.

At the 2015 United Nations Climate Change Conference in Paris, world leaders agreed that the global mean temperature increase should be limited to well below 2°C, and if possible to 1.5°C, above pre-industrial levels. To have a reasonable chance of achieving the Paris Agreement goals, it is projected that global greenhouse gas emissions would have to peak around 2020 followed by rapid decarbonisation to zero net emissions by 2050. However, no country among the major emitters is currently on track to achieve such a drastic transformation of its economy. Even if all countries achieved the emissions cuts that they agreed in Paris, it is projected that the global temperature would rise by at least 2.4°C and potentially more than 3°C by 2100.

Major environmental, social, and economic impacts are expected at such levels of warming, lending further urgency to this matter. It remains unclear whether solar radiation management will ever be technically, politically, and socially feasible. However, if it could be implemented, it would be the only climate policy option that could significantly slow or stop the rise in global temperatures over short timescales. Therefore, if humanity does not reduce emissions at rates far greater than those previously observed or even promised, these techniques would probably be the only option for achieving the ambitious targets agreed in Paris. It is thus important to discuss whether solar radiation management could be an acceptable measure in climate policy under certain conditions and, if so, how it might best be used to limit risk from rising temperatures.

What is the state of research on radiation management?

Natural sciences and engineering

The main proposed solar radiation management techniques are hypothetical in that they have not been tested at scale. So far there have only been two outdoors experiments aimed at understanding components of a potential system, though several proposals for further small-scale field experiments are under development. Understanding of the potential risks and benefits of the proposed techniques has instead largely been based on natural analogues, computer modelling, laboratory experimentation, and basic knowledge from in situ and satellite measurements of parameters like temperature and precipitation.

There is a scientific consensus that none of the proposed techniques should be considered a substitute for mitigation or adaptation. However, research results indicate that solar radiation management would be capable of reducing many of the impacts of rising temperatures, such as heat waves, species loss, glacier retreat, the rate of sea ice melt, the rate of sea level rise, and agricultural losses. Its effects would be expected to vary regionally, for instance with stronger relative cooling in the tropics than at the poles. Different types of solar radiation management are expected to perform differently with regard to regional outcomes. However, modelling studies indicate that it might be possible to design and deploy solar radiation management techniques in a way that would limit regional differences, and could significantly reduce climate change impacts, especially in terms of temperature and precipitation, in the majority of regions around the world.

There are high levels of uncertainty about the full range of impacts of solar radiation management, including unwanted consequences. For example, research has indicated that injecting aerosol particles into the stratosphere could influence the levels of stratospheric and even ground-level ozone. This would have uncertain effects on ultraviolet radiation and potentially both positive and negative impacts on human and ecosystem health. Furthermore, some types of proposed particles would also absorb infrared radiation from the Earth, heating up the stratosphere and affecting airflows there.

Finally, the climatic effects of solar radiation management would only last as long as deployment was maintained. In the event of its discontinuation, global surface temperatures would rise rapidly towards the levels that would have been expected in its absence. If solar radiation management were being used to mask a large amount of warming, its sudden cessation could be quite damaging as human and natural systems would have less time to adapt. This effect is often referred to as 'termination shock'. To reduce the likelihood of such rapid warming, any future deployment would need to include careful consideration of backup systems and policies.

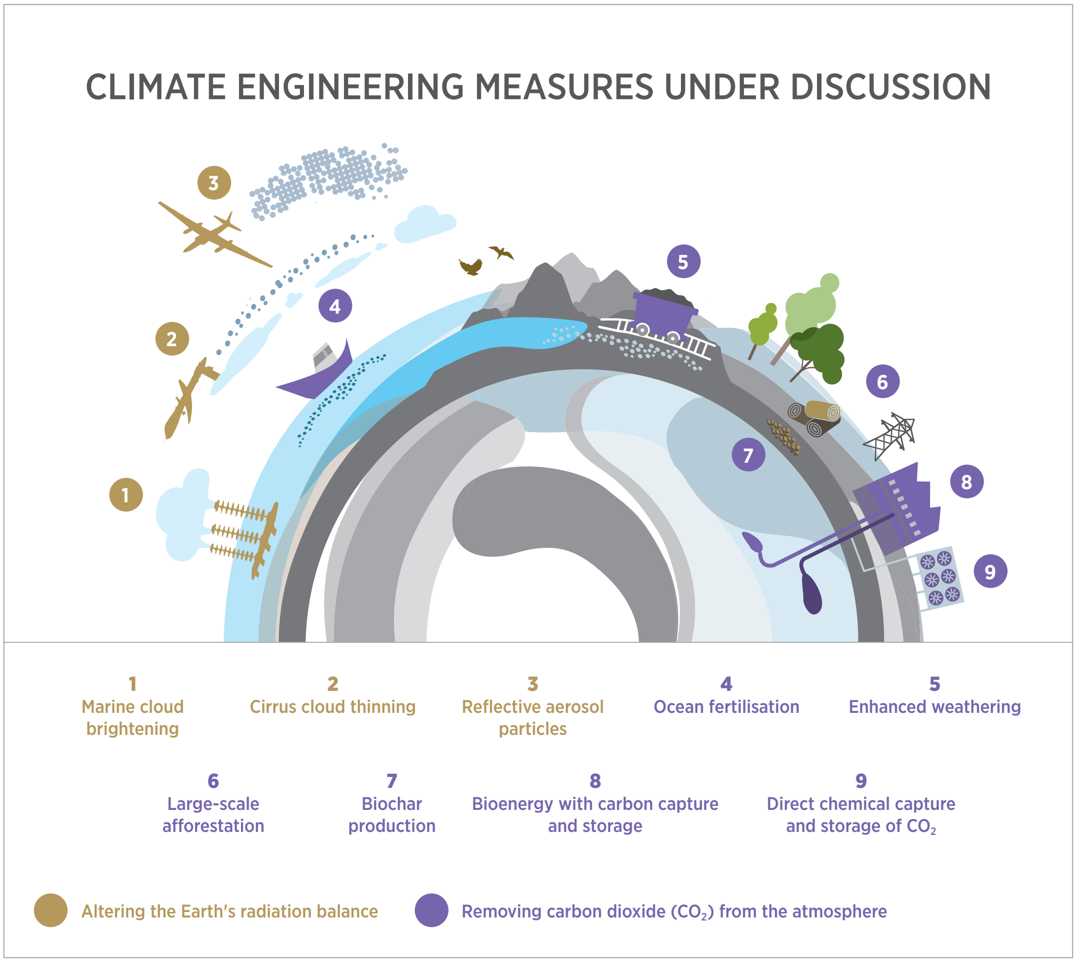


Figure 1: Climate engineering measures can be divided into two groups: those intended to remove atmospheric carbon dioxide and those intended to alter the Earth's solar radiation balance.

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Social science and humanities

The political, economic and social aspects of solar radiation management have been assessed via economic models, analogical comparisons, scenarios, public engagement exercises, and analyses of how it is framed in academic, policy, and media articles. These methods have been used to analyse, simulate, or imagine a variety of plausible benefits and risks in areas as diverse as global climate negotiations, energy politics and economic repercussions, intellectual property, state and human security, and humanity's relationship with the natural world. The potential impact that discussion of solar radiation management may have on efforts to reduce carbon emissions is a prominent area of questioning.

Researchers have also begun investigating the moral and ethical dimensions of solar radiation management such as the unequal capacity between states to research and deploy the technologies, the ethical acceptability of global action that might not improve everyone's situation, the implications of solar radiation management as judged by different conceptions of justice, the question of how potential harms might be compensated, and the acceptability of applying technological approaches at a global systems level.

Is solar radiation management politically feasible?

To be considered feasible, solar radiation management would need to be able to reduce climate risks with acceptably low side effects, and it is not clear how to determine what is "acceptably low" for the range of stakeholders and decision-makers involved. It is also uncertain how attitudes will change over time in response to changing perceptions of climate change and the results of ongoing research. Independent of expected impacts, some might reject solar radiation management on principle. The crafting of a legitimate global decision to deploy would represent a significant political challenge. Therefore, it is currently impossible to say with any certainty whether any approach would be socio-politically feasible.

How could solar radiation management be governed?

The term 'governance' has been used in this context to refer to concepts ranging from international regulations restricting deployment to domestic policies enabling relevant research and informal norms guiding individual research practices. Researchers have assessed and proposed a range of potential institutions and mechanisms for the governance of solar radiation management, at every stage from research and field experiments to sustained deployment.

Governance of small-scale field research

Due to increasing calls for more outdoors experimentation, an immediate concern is how to govern small-scale field research. While some mechanisms already exist in the form of local and national environmental regulation, professional norms, research funding procedures, and international agreements, several issues remain. A pressing question is what, if any, types of small-scale field research should proceed and be prioritised. It remains to be decided whether additional risk evaluation procedures are required, how funding for safe and informative research projects can be mobilised, and what level and form of public engagement is required during decision-making processes. Existing governance frameworks focusing on early stages of research and technology development might offer lessons. Ongoing assessments and discussions are also exploring whether additional rules are necessary – potentially at the international level – or if existing governance mechanisms can manage the risks of field research. If it is decided that solar radiation management research warrants additional and novel governance arrangements, such research would need to be defined in a manner that distinguishes it from 'normal' climate research.

Governance of deployment and large-scale testing

Assessments of the potential roles that international legal institutions and mechanisms could play in the governance of large-scale testing and deployment are ongoing. These have taken place alongside, and have been informed by, decisions of the Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD) and the London Convention and London Protocol, which focuses on marine-based geoengineering approaches. There is currently no comprehensive international mechanism for governing the use of solar radiation management. Some have called for existing treaty regimes to be adapted, while others have concluded that a new international agreement would be needed.

At this stage it is unclear what form deployment would take, or what the international political environment might be like at the time. Deployment governance challenges that are being considered now include: How can an inclusive and accountable decision-making process be put in place? What risks and benefits, and whose interests, would have to be taken into consideration when decisions about deployment are made? How can an adequate global monitoring and evaluation system be put in place? What forms of compensation would be available for climate impacts that occur and are ascribed to such interventions? What steps could guard against a 'moral hazard' response, where the prospect of solar radiation management resulted in significantly lower mitigation efforts? What steps could guard against a 'slippery slope' response, where small-scale research could lead to larger scale research and even deployment without sufficient critical reflection?

SUMMARY

- Solar radiation management is not an alternative to reducing greenhouse gas emissions as it addresses different climate risks to emissions mitigation. Increasing greenhouse gas levels in the atmosphere would not be directly addressed by solar radiation management, which would imperfectly mask the warming caused by these gases.

- It remains unclear whether solar radiation management will ever be technically, politically, and socially feasible. If it could be implemented, however, it would be the only climate policy option that could significantly slow or stop the rise in global temperatures over short timescales.

- When simulated in computer models, some forms of solar radiation management deployment have consistently been found to reduce the worst risks and impacts of climate change. However, some regional differences remain and the modelling evidence is still limited, leaving large uncertainties.

- Even if technical challenges prove surmountable, the social and political challenges of solar radiation management are likely to be significant.

- There is currently insufficient knowledge about both the physical and societal aspects of solar radiation management to make informed political decisions. In order to develop the capability for informed decision-making, further research will be needed in the natural and social sciences, engineering, and the humanities, accompanied by broad societal engagement.

IASS POTSDAM

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