CLIMATE OVERSHOOT COMMISSION

Additional Information on SRM

The following brief provides additional information on SRM, specifically with regard to potential impacts, distributional effects, regional deployment, social acceptability, current research, and research gaps. Knowledge about options other than SAI and MCB is limited to such a degree that they are not covered in what follows.

Potential Impacts

In general, the severity of impacts from SRM would strongly depend on the combination of the magnitude of the intervention - how much SRM is implemented - and the rate of the intervention - how quickly SRM is implemented. In addition, the impacts from SRM must be assessed relative to those from climate change without SRM. Beyond that, the impacts of SRM depend on the type of SRM that is deployed. In some cases, a moderate amount of SRM would diminish some aspects of climate change while a larger intervention would exacerbate them. Note that the word “impact” here means a change in either direction.

1. **Stratospheric Aerosol Injection (SAI)**

Potential climate impacts *other than reduced warming*:

/ Changes in regional precipitation patterns; this would also affect runoff patterns.

/ Reduced temperature and precipitation extremes.

/ Reduced tropical cyclone intensity.

/ Reduced Arctic sea ice melt.

/ Decrease in direct and increase in diffuse sunlight at the surface.

/ Slightly whiter skies (although perhaps barely perceptible).

/ Stratospheric heating, which could result in residual winter warming over Eurasia.

/ Delayed recovery of the ozone layer (if sulfate used), which would result in increased exposure to harmful ultraviolet radiation at the surface.

/ Reduced surface ozone, which would reduce pollution and benefit human health.

Modeling suggests that a hypothetical SAI deployment designed to slow the rate of global warming by half would improve regional climate impacts, including mean annual temperature, maximum annual temperature, precipitation minus evaporation (i.e., runoff), and maximum 5-day precipitation, compared to an otherwise identical scenario in which SAI was not deployed.

Potential impacts on human and natural systems:

- Changes in crop yields depending on species, latitude, etc.
- Changes in land and ocean ecosystem productivity depending on type, structure, latitude, etc.
- Reduced risk of heat stress to corals.
- Reduced risk of wildfires.
- Reduced sea level rise.
- In general, all other impacts of climate change would also be reduced.

2. Marine Cloud Brightening (MCB)

Potential climate impacts *other than reduced warming*:

- Changes in regional precipitation patterns; this would also affect runoff patterns.
- Inherently patchy application would result in patchy effects at the global level, which could exacerbate some climate impacts.

Potential impacts on human and natural systems:

- Changes in regional ocean productivity.
- Changes in crop yields depending on species, latitude, etc.
- Reduced heat stress for corals.
- Changes in ecosystem productivity on land.
- Sea salt deposition over land.

Distributional Effects

Similar and related to potential impacts, the global distributional effects of SRM will depend on the magnitude of the intervention undertaken, while their assessment will depend on comparing them to the distributional effects of climate change in the absence of SRM. In general, insofar as low-latitude and developing countries are expected to suffer disproportionately from climate change, reducing climate change can be expected to benefit them disproportionately. To the extent that SRM leads to a net reduction in climate impacts (see above), SRM can therefore be expected to benefit developing countries disproportionately. Modeled evidence of the distributional effects of SRM is limited, but what does exist shows that using SAI either to stop or reverse global warming would reduce income inequality among countries (Harding et al. 2020).

Overall, the available evidence indicates that the climate, environmental, and societal impacts, and distributional effects of SRM would depend on how SRM were deployed. Moderate and measured uses of SRM, particularly SAI, appear capable of improving conditions for people and nature compared to not using it. Immoderate and unmeasured uses, however, appear capable of making conditions worse than they would have been without SRM. The consequences of SRM, in other words, would depend largely on how deployment was designed and managed, which in turn would depend on broader questions of politics and governance.

Regional Deployment

For SAI, regional deployment would be limited to the poles. Wherever they were injected, stratospheric aerosols would circle the Earth and move toward the nearest pole. Consequently, the only regions to which the direct effects of deployment could be confined would be the Arctic and Antarctic. Because deployment in one hemisphere only would shift precipitation in the tropics, regional deployment over either pole should be accompanied by regional deployment over the other.

By contrast, MCB might be capable of cooling small patches of ocean surface, which could be aggregated at the regional level. Such patchy application would, however, result in patchy regional effects, which could exacerbate some climate impacts.

Social Acceptability

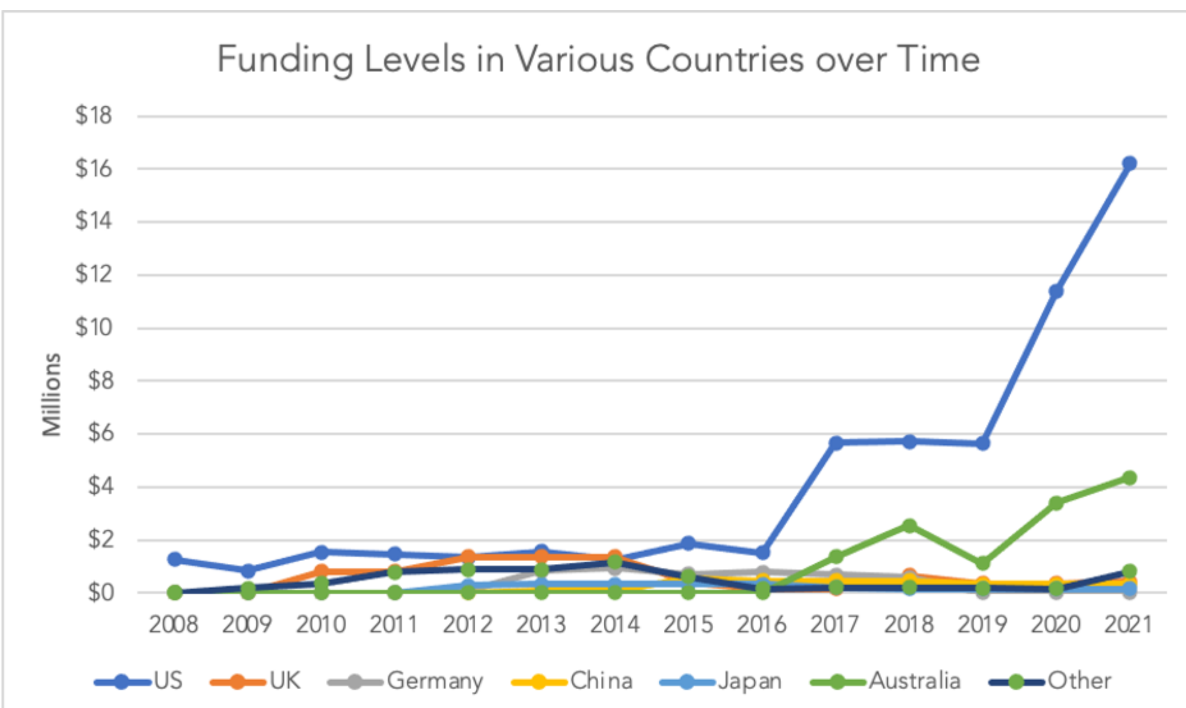
The public acceptability of SRM - or lack thereof - is a critical aspect of research on and potential development of the technology. A precondition of acceptability, however, is awareness, and survey data show a widespread lack of familiarity with SRM across the Global North and South. A systematic review of the literature on public perceptions of SRM, for example, concluded that "familiarity and awareness of geoengineering technologies are quite low" worldwide (Cummings, Lin, and Trump 2017). Nevertheless, in general, publics consistently oppose the use of SRM at this time but are more supportive – often reaching a majority of respondents – of SRM research.

Current Research

The following table details specific SRM research projects around the world over the period 2008-2021 whose total funding was greater than half a million dollars. Global funding for SRM research from 2008 to 2021 averaged less than $7 million per year. Perhaps surprisingly, most research has been interdisciplinary rather than strictly natural science-based, with governments and philanthropies providing roughly equal amounts of funding.

The following figure shows changes in funding by country over time. Clearly, the US is the global leader in funding for SRM research, followed by a few other Western countries and China. By comparison, the amount of SRM research taking place in the Global South is extremely limited. (The nonprofit Degrees Initiative, however, is currently working to support SRM research projects led by investigators from the Global South.)

Annual Funding for SRM Research by Country 2008-2021



Note: "Other" includes Canada, Denmark, EU, Finland, France, India, Norway, and Sweden.

Source: Horton 2022[1].

Outdoor Experiments

Outdoor research on SRM has been extremely limited, with no explicitly SRM-oriented experiments conducted to date. For SAI, a UK field test to evaluate a tethered balloon aerosol delivery system, planned as part of the government-supported Stratospheric Particle Injection for Climate Engineering (SPICE) project, was canceled in 2012 due to intellectual property issues. In Sweden, an equipment test flight planned as part of Harvard University's small-scale Stratospheric Controlled Perturbation Experiment (SCoPEx) was canceled in 2021 in response to opposition. For MCB, delivery equipment field tests were carried out above the Great Barrier Reef in Australia in 2020 and 2021.

Research Gaps

Critical SRM research gaps include:

- Need to improve understanding and reduce uncertainties regarding how SRM would interact with fundamental atmospheric processes, including through observation, laboratory experiments, and small-scale outdoor experiments.
- Need to improve predictions of climate system responses to SRM, including at regional scale and for alternative deployment schemes, by using climate models.
- Need to improve knowledge of environmental and societal impacts including those noted above.
- Across the board, there is a need for both more research conducted by investigators from the Global South, and more international collaboration in SRM research.

References

- Cummings, C.L., Lin, S.H., and B.D. Trump. 2017. Public Perceptions of Climate Geoengineering: A Systematic Review of the Literature. Climate Research 73: 247-264.
- IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University

[1] Horton, J.B. 2022. *Solar Geoengineering Landscape Analysis*. Rockefeller Foundation.

Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

- Harding, A.R., Ricke, K., Heyen, D., MacMartin, D.G., and J. Moreno-Cruz. 2020. Climate Econometric Models Indicate Solar Geoengineering Would Reduce Inter-Country Income Inequality. Nature Communications 11: https://doi.org/10.1038/s41467-019-13957-x.
- Irvine, P., Emanuel, K., He, J., Horowitz, L.W., Vecchi, G., and D. Keith. 2019. Halving Warming with Idealized Solar Geoengineering Moderates Key Climate Hazards. Nature Climate Change 9: 295-299.
- Horton, J.B. 2022. Solar Geoengineering Landscape Analysis. Rockefeller Foundation.
- National Academies of Sciences, Engineering, and Medicine 2021. Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance. Washington, DC: The National Academies Press. https://doi.org/10.17226/25762.