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Solar Radiation Management Responses to Climate Change

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ISSUE

Solar radiation management (SRM) is a potential response to climate change that has seen increased attention, and generated sharp controversy, in the past two years. SRM seeks to offset climate heating from elevated atmospheric greenhouse gases (GHGs), by decreasing the sunlight absorbed by the Earths' surface. Proposed approaches include increasing the reflectivity of the land surface (by making forests, crops, or built surfaces whiter); of the ocean (by floating popcorn or engineering plankton to blow bubbles); or of the atmosphere (by making more or whiter clouds, or spraying reflective particles); or placing screens in space to shade part of the sun's disk. The approach that looks most effective and reversible at present involves injecting reflective particles, sulfate aerosols or some engineered particles, into the stratosphere, where they stay a year or so. Another approach attracting interest is injecting sea-salt aerosols into the lower atmosphere to make more and brighter marine clouds.

BACKGROUND

SRM approaches are cheap, fast, and imperfect.

They are cheap and fast because they apply extreme physical leverage: a few grams of sulfate particles in the stratosphere can offset the heating of a ton of atmospheric CO_2. Lifting aerosols costs ~ $1,000 a ton with present methods like spraying them from aircraft or shooting them from naval guns. New approaches that reduce lifting costs or mass requirements could cut this cost greatly, but even at current costs SRM could offset this Century's projected global heating for a few billion dollars a year – about a thousand times cheaper than achieving the same cooling by emission cuts. It is likewise SRM's tiny mass requirements that make it fast. Aerosol injection could cool the world a few degrees within months – as shown by explosive volcanic eruptions like Mt. Pinatubo in 1991, which cooled the world 0.5 C in less than a year.

All identified SRM approaches are imperfect, however. This is not just that they bring their own environmental risks, although these are real and potentially serious. Stratospheric sulfur injection would probably slightly worsen ozone depletion and acid deposition, and would move some sunlight from the direct beam to the diffuse sky, affecting plant productivity (mostly up), solar power potential (down), and the appearance of the sky (whiter) and sunsets and sunrises (more vivid). Thus far, identified impacts look small, but unforeseen risks from such large interventions are a serious concern.

More seriously, SRM cannot fully offset the environmental harms caused by greenhouse gases. These limits to SRM's effectiveness – in global and regional climate, and the non-climate effects of GHGs – are so tightly linked to the basic geophysical mechanisms by which SRM operates that further research is unlikely to reduce them.

With elevated GHGs, SRM can restore global temperature to any desired level, but not the original climate and environment. Even at global scale, because SRM cools the Earth at the surface to offset warming aloft, it controls precipitation more strongly than temperature: cooling by SRM leaves the world drier than cooling it the same amount by cutting GHGs. Regional climates under high GHGs and SRM are likely to diverge further from the unperturbed climate. Early model studies suggest there may be large disruptions in monsoons and regional wind patterns, but the uncertainties in these projections are large. SRM would also do nothing about the non-climate effects of elevated GHGs, mainly ocean acidification by increased CO_2 uptake and direct CO_2 effects on ecosystems.

Cheap, fast, and imperfect: these attributes define the opportunities, risks, and challenges of SRM. Because SRM can act so fast, it is the only way we might hope to slow or stop severe climate changes after major uncertainties are resolved and we know bad things are happening. This potential to act fast with more knowledge is the main reason to research SRM and develop the capacity to deploy it if necessary, even though some impacts may be irreversible by the time we know they are happening (e.g., loss of major ice sheets; transformation of ecosystems by fire or pests). Because SRM is so imperfect, it cannot be a complete climate strategy, but must be developed in parallel with mitigation and adaptation, which both remain essential. And because SRM is so cheap, it raises the temptation to rely on it too much and neglect those other elements: there are already boosters claiming SRM makes mitigation and adaptation unnecessary. SRM's low cost also poses the risk of unilateral action. Most nations and many non-state groups and even individuals could afford to do it: one scientist recently guessed that any of the world's fifty richest people can buy an Ice Age.

SRM's largest risks are probably political, related to how it may influence society's overall response to climate change. In addition to the temptation of cheap SRM sapping already weak resolve for mitigation, two other such risks have been identified. First, gradual expansion of SRM could lead to a state (akin to addiction) in which we cannot stop, because turning off several degrees of global cooling would impose all that heating in a year or two. Second, the prospect of SRM may stoke global conflict. What measures should be deployed, at what scale? If we decide to use a little SRM to shave a near-term temperature peak as part of a low-cost response portfolio, how do we define and enact such an integrated global strategy? Alternatively, if we decide to use SRM only in an emergency, what counts as one and who gets to decide? How do we handle claims of inadvertent damage from SRM, or hostile use? And how do we respond to unauthorized unilateral deployment?

LATEST DEVELOPMENTS

Intensive discussions over the past year on scientific, technical, environmental, and political aspects of SRM have produced an emerging consensus on a few points, and identified many unanswered questions.

- SRM research must proceed, as a precaution against risks of severe climate change that may arise from continued failure to cut emissions, bad outcomes on climate or impact-related uncertainties, or some combination of these.

- In addition to laboratory and modeling work, initial SRM research should include tiny field experiments to study key processes, so small in scale that their impacts are assuredly minor.

- Research programs should be international, fully transparent about methods and results (i.e., no proprietary work), and include public consultation and independent environmental and risk assessment from the start.

- Legitimate governance institutions for SRM must be in place before any decisions on deployment or large-scale field trials. These will have to manage foreseeable conflicts over deployment decisions, allocation of risks and benefits, evaluation of outcomes, response to failures and damage claims, and response to unauthorized or unilateral deployment. No existing international institution has the required capabilities, and there is presently no consensus on the desirable shape of such a regime. Large uncertainties, including the desired balance between promotion and control of SRM, make early pursuit of a treaty inadvisable. Rather, consultations on governance processes should start now, in consultation with initial programs of research and assessment, to build legitimacy and consensus on governance approaches as knowledge about SRM capabilities and risks expands.