A sun reflector for Earth? Scientists explore the potential risks and benefits

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Nine of the hottest years in human history have occurred in the last decade. Without a major shift in this climate trajectory, the future of life on Earth is in question. Should humans, whose fossil-fueled society is

driving climate change, use technology to put the brakes on global warming?

Every month since September 2019 the Climate Intervention Biology Working Group, a team of internationally recognized experts in climate science and ecology, has gathered remotely to bring science to bear on that question and the consequences of geoengineering a cooler Earth by reflecting a portion of the sun's radiation away from the planet—a climate intervention strategy known as solar radiation modification (SRM).

The group's seminal paper, "Potential ecological impacts of climate intervention by reflecting sunlight to cool Earth," was published in the most recent *Proceedings of the National Academy of Sciences* (*PNAS*).

"Participating in this working group has been quite eye-opening for me," said co-author Peter Groffman, an ecosystem ecologist at the Advanced Science Research Center at The Graduate Center, CUNY and the Cary Institute of Ecosystem Studies. "I was unaware that modeling climate intervention was so advanced, and I think that climate modelers were unaware of the complexities of the ecological systems being affected. It is a strong reminder of the importance of the need for multi-disciplinary analysis of complex problems in environmental science."

The interdisciplinary team is co-led by Phoebe Zarnetske, community ecologist and associate professor in Michigan State University's Department of Integrative Biology and the Ecology, Evolution, and Behavior program, and ecologist Jessica Gurevitch, distinguished professor in the Department of Ecology and Evolution at Stony Brook University.

Conversations between Gurevitch and climate scientist Alan Robock, distinguished professor in the Department of Environmental Sciences at

Rutgers University, gave rise to the pioneering group, which is more aware than most that geoengineering Earth's atmosphere is more than just a science-fiction scenario.

"There is a dearth of knowledge about the effects of climate intervention on ecology," said Zarnetske. "As scientists, we need to understand and predict the positive and negative effects it could have on the natural world, identify key knowledge gaps, and begin to predict what impacts it may have on terrestrial, marine, and freshwater species and ecosystems if it were adopted in the future."

The costs and technology needed to reflect the Sun's heat back into space are currently more attainable than other climate intervention ideas like absorbing carbon dioxide (CO_2) from the air. The working group anticipates their lively discussions and open access paper will encourage an explosion of scientific investigation into how a climate intervention strategy known as solar radiation modification (SRM), in tandem with greenhouse gas emissions reduction, would affect the natural world.

The feasibility of planetary-wide SRM efforts hinge on accurate predictions of its myriad outcomes provided by the well-established computer simulations of the Geoengineering Model Intercomparison Project (GeoMIP). The *PNAS* paper lays the foundation for expanding GeoMIP's scope to include the incredible range and diversity of Earth's ecosystems.

"While climate models have become quite advanced in predicting climate outcomes of various geoengineering scenarios, we have very little understanding of what the possible risks of these scenarios might be for species and natural systems," Gurevitch explained. "Are the risks for extinction, species community change, and the need for organisms to migrate to survive under SRM greater than those of climate change, or does SRM reduce the risks caused by climate change?"

"Most of the GeoMIP models only simulate abiotic variables, but what about all of the living things that are affected by climate and rely on energy from the sun?" Zarnetske added. "We need to better understand the possible impacts of SRM on everything from soil microorganisms to monarch butterfly migrations to marine systems."

Zarnetske's Spatial and Community Ecology Lab (SpaCE Lab) specializes in predicting how ecological communities respond to climate change across scales from the microcosm to the global, making it uniquely poised to assist the working group in illuminating vital data for future SRM scenarios such as stratospheric aerosol intervention (SAI), the focus of the paper.

SAI would reduce some of the Sun's incoming radiation by reflecting sunlight back into space, similar to what happens after large volcanic eruptions. Theoretically, it would be possible to continuously replenish the cloud and control its thickness and location to achieve a desired target temperature.

But the paper reveals the under-researched complexity of cascading relationships between ecosystem function and climate under different SAI scenarios. In fact, they argue, climate change mitigation must continue regardless of whether SRM is adopted, and the question remains whether some or any SRM can be beneficial in addition to decarbonization efforts.

"Although SAI may cool Earth's surface to a global temperature target, the cooling may be unevenly distributed, affecting many ecosystem functions and biodiversity," Zarnetske said. "Rainfall and surface ultraviolet radiation would change, and SAI would increase acid rain and would not mitigate ocean acidification."

In other words, SRM is not a magic bullet for solving climate change.

Until the working group's efforts inspire new research into the effects of different climate intervention scenarios, SRM is more akin to a shot in the dark.

"We hope that this paper will spark a lot more attention to this issue and greater cooperation between scientists in the fields of climate science and ecology," added Gurevitch.

The Climate Intervention Biology working group is funded by the National Science Foundation and will host sessions at two upcoming scientific conferences: "Biosphere Responses to Geoengineering" at The American Association for the Advancement of Science (AAAS) Annual Meeting this month, and at The Ecological Society of America in August, 2021.

More information: Phoebe L. Zarnetske el al., "Potential ecological impacts of climate intervention by reflecting sunlight to cool Earth," *PNAS* (2021). www.pnas.org/cgi/doi/10.1073/pnas.1921854118

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