Blocking the sun to control global warming

September 16 2021, by Nancy Bazilchuk

When Mt Pinatubo erupted in 1991, it ejected 20 million tonnes of sulphur dioxide into the atmosphere. Over the months following the eruption, the aerosols formed a global layer of sulphuric acid haze. Global temperatures dropped by about 0.4 °C from 1991–1993. That's a natural form of solar geoengineering that humans could try to mimic to cool the planet. Credit: Dave Harlow, United States Geological Survey/Wikimedia Commons/Public Domain

It sounds like something out of a bad science fiction movie—artificially blocking sunlight to keep global warming from overheating the Earth. Nevertheless, a small cadre of researchers is studying the option—so that if humankind ever needs to use it, it will be an informed decision.

The latest report from the Intergovernmental Panel on Climate Change (IPCC), released in early August, made it clear that humankind needs to take immediate action to curb global warming. There's hope that international climate talks in Glasgow this November may finally result in strong enough greenhouse gas emission limits to make a difference.

But just in case, an international group of researchers, including NTNU's Helene Muri, has been studying a technology called solar geoengineering as an action of last resort.

Solar geoengineering is exactly what it sounds like, where various technologies are used to block sunlight and cool the Earth. Typically, three main approaches—none of which is currently technologically ready—are being studied for their ability to block sunlight and lower ground temperatures. (See box)

Muri, a senior researcher at the university's Industrial Ecology Programme, has spent the last decade looking at how solar geoengineering might—or might not—work.

In June, she and her colleagues from the US, China and the UK published a paper in *Nature Food* that used computer models to assess solar geoengineering's potential effects on agriculture in a high emission world. Their findings sparked international media coverage because they found that solar geoengineering in those scenarios could actually have a positive effect on crop growth from higher humidity.

Other studies that used simpler models found either a limited effect or

losses for rainfed crops, since there could be less rainfall with the lower temperatures that come with solar geoengineering—depending on the way the technology is used to cool the Earth.

Now, as the world prepares to debate limits on CO_2 emissions during November's climate talks, it's worth a look at the measures being examined by researchers like Muri—and an assessment of their possible risks and pitfalls.

Band-aid or tourniquet?

Any discussion of solar geoengineering has to acknowledge that it's far from a perfect fix, Muri says.

"Solar geoengineering, no matter how well we do it, will never perfectly offset the effects of climate change," she said.

The problem is that solar geoengineering may cool the Earth, but doesn't get rid of the excess carbon dioxide and other heat-trapping substances in the atmosphere. And carbon dioxide does more than simply warm the Earth.

It fertilizes plants—which could be a good thing—but because much of it gets dissolved in sea water, it makes the oceans more acidic.

"There will always be things that you cannot fix with solar geoengineering, specifically ocean acidification," she said. "A more acidic ocean affects everything in the food chains in the ocean, including coral reef diebacks, which is terrible for the ecosystem as a whole. That becomes evident as soon as you really start looking at it. There is no one silver bullet. It's not the one solution that can fix everything."

Muri says that any discussion of geoengineering also assumes that CO_2

emissions will be dealt with at the same time any solar geoengineering is deployed.

Alan Robock, a climate researcher at Rutgers University in the US who is leader of an international cooperative research project of called GeoMIP, of which Muri is a part, agreed.

"It's not a solution to global warming at its best. If it were ever used as a band-aid—or a tourniquet—it doesn't solve the root problem," he said.

Many unknowns, but still need to know

Muri says there is still much that is unknown about solar geoengineering, in part because most climate change research is focused on issues other than geoengineering.

"Just to put the level of research into context, for the last five to 10 years, there have been about 100 to 130 papers published per year on solar geoengineering," she said. "When it comes to climate change it's more like 30,000 papers per year over that period. The important thing is that it is a vastly, hugely different amount. It's just a minority of effort and funding going into researching solar geoengineering."

At the same time, she says, the US National Academies of Sciences, Engineering and Medicine published a comprehensive report on solar geoengineering that said the urgency of the risks posed by climate change meant that "the U.S. should pursue a research program for solar geoengineering—in coordination with other nations, subject to governance, and alongside a robust portfolio of climate mitigation and adaptation policies." The report recommended US funding of about $100 million-$200 million over the first five years.

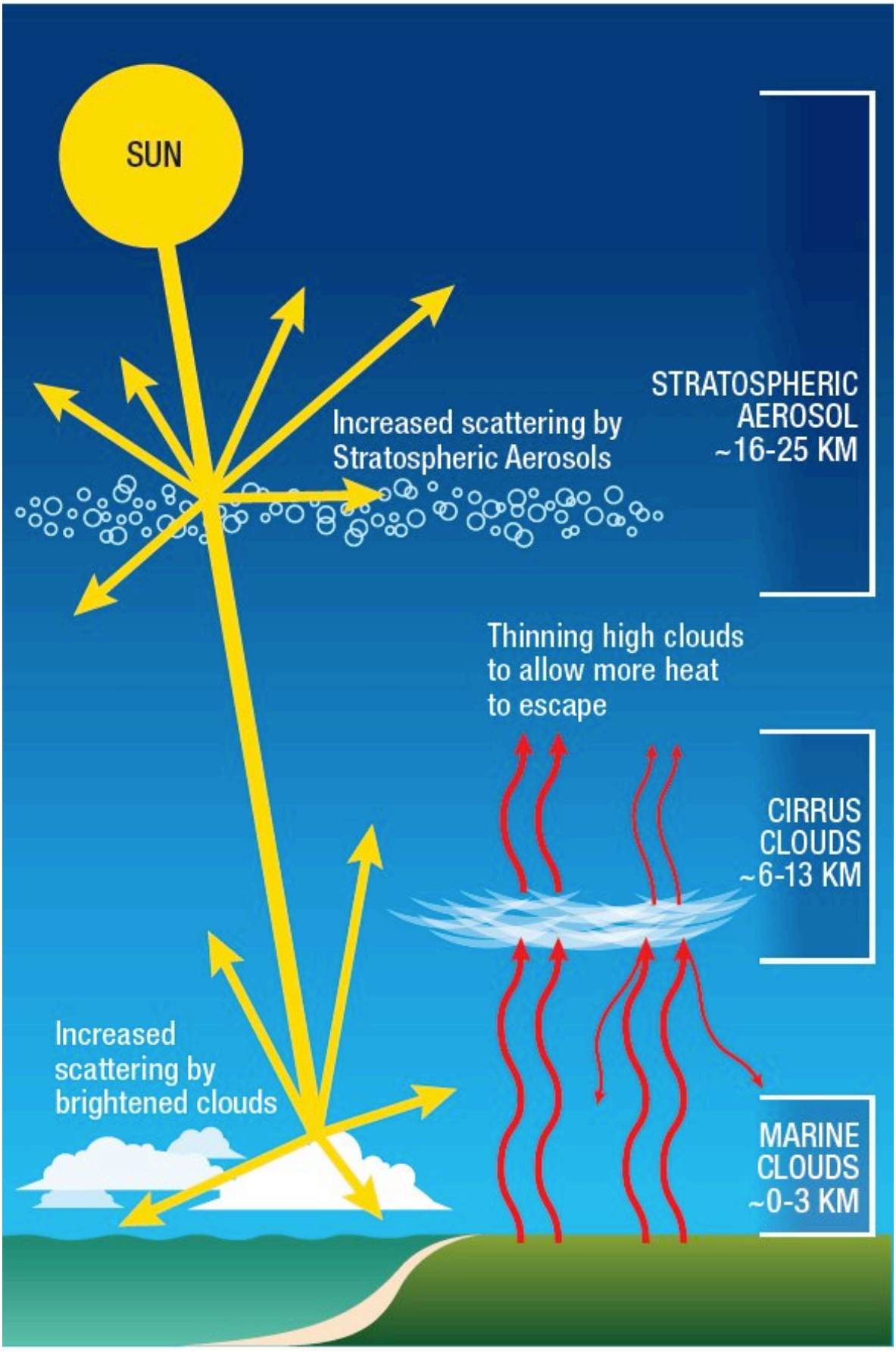
Muri says that climate researchers' main focus needs to remain on

climate change itself, because society needs to know what the effects will be, how to adapt, and how to mitigate these effects. Nevertheless, she says, researchers do need to study solar geoengineering to see if it could be helpful as a stopgap measure while the world transitions away from fossil fuels.

"The question is if it could contribute to reduce some level of harm from climate change for a certain period, whilst we are trying to sort out both emissions of CO_2 and concentrations of CO_2 within the climate system," she said. "Nobody sees it as a one and only solution, but it's not clear yet whether it could be helpful or not. At the moment, there are too many unknowns and uncertainties to really say whether it's overall a good idea or a bad idea."

Robock agrees.

His group at Rutgers University is "doing research to evaluate the risks of doing solar geoengineering versus the risks of not doing it. And that's the information that governments will need in the future to decide whether or not to ever implement it," he said. "I spend millions of dollars of taxpayer money to do my research. And if I find a danger to society, it's my obligation to warn people about it."


SUN
Increased scattering by
Stratospheric Aerosols
STRATOSPHERIC
AEROSOL
~16-25 KM
Thinning high clouds
to allow more heat
to escape
CIRRUS
CLOUDS
~6-13 KM
Increased
scattering by
brightened clouds
MARINE
CLOUDS
~0-3 KM

Three main types of solar geoengineering that are now being studied. Credit: US National Academy of Science

A cooler Earth but potentially changed monsoons

Robock's group is looking at the benefits and risks of using stratospheric aerosols to cool the planet, which emulate a volcanic eruption.

"Benefit number one would be, if you could do it, you would reduce global warming, and many of its risks," Robock said. "We know that if you could get the aerosols up there, it would work because it doesn't involve creating or affecting clouds in the troposphere, it's just putting a shield up there to reflect sunlight."

Researchers know that big volcanic eruptions, like the 1991 eruption of Mount Pinatubo, cooled the Earth. But these natural solar geoengineering experiments have also given them the ability to observe other pitfalls, Robock said.

"We know that there were other things that were not so good; (the eruption) destroyed ozone," he said. "And you actually get a huge reduction of monsoon rainfall. We observed that after Mount Pinatubo."

Volcanic eruptions only cause the Earth to cool for a year or two, because the aerosols eventually dissipate. However, if stratospheric aerosols were to be used as solar geoengineering to cool the Earth, their use could alter monsoon rainfall for a much longer period, which could result in famine, Robock said.

Some modeling has shown that solar geoengineering could in fact have less of an impact on monsoons than global warming, but nevertheless, the issue illustrates just how difficult making these predictions are.

Who decides?

Then there are issues such as insect-borne diseases, like malaria, Muri points out. How would solar geoengineering affect mosquito populations and the potential spread of malaria?

And what if a failure to cut CO_2 emissions and reduce global warming results in devastating heat waves, where thousands of people die? Is that enough to outweigh other negatives?

"There are still so many areas where we don't know enough," she said.

Finally, there are areas that are far outside of what climate scientists who study the physical effects of climate change can predict. The biggest question is who decides what the temperature of the planet should be?

The political decision making surrounding solar geoengineering is daunting, if you consider the difficulty the nations of the world have already had in trying to agree to curb CO_2 emissions, Muri said.

"How would one deal with geoengineering in terms of geopolitics and governance?" Muri said. "We need to develop regulations. Who sets the thermostat and how would you go about agreeing on something like that?"

In a companion piece to Muri and her colleague's article on geoengineering and agriculture, Ben Kravitz, an assistant professor at Indiana University's Earth and Atmospheric Sciences Department, summed it up like this.

"Agriculture is one important piece in our understanding of the effects of climate engineering," he wrote. "Gaining a better picture of the impacts of climate engineering requires looking at numerous effects in addition to food supply, including water security, geopolitics, and environmental justice…. It is important to figure out whether climate engineering would ultimately be more or less risky than climate change (and to whom)."

What is solar geoengineering?

Researchers are studying a number of engineering approaches as possible methods for cooling the planet. The three described here have been identified by a March report by the US National Academies of Sciences, Engineering and Medicine as meriting further study. The three approaches either rely on controlling the amount of sunlight reaching the Earth, or reducing the amount of heat trapped by the atmosphere.

Stratospheric aerosol injection

This technique requires injecting aerosol particles, like sulfates or precursor gases, like sulfur dioxide, into the stratosphere, which is the layer of air 10 to 50 km above the Earth's surface. Most studies are looking at placing aerosols at about 20 km above the Earth, where the particles scatter and reflect solar radiation to cool the planet. This technique mimics what happens with large volcanic eruptions. When Mount Pinatubo erupted in 1991, it sprayed 15 to 20 megatons of sulfur dioxide into the atmosphere, which cooled the Earth by about 0.4 degrees Celsius for two years. Currently, however, there are no planes capable of flying into the stratosphere to do this.

Cirrus cloud thinning

This technique involves spraying chemicals into cirrus clouds, at about 6-13 km above the Earth's surface, to cause them to thin or disappear. The clouds trap heat, so thinning them or reducing them cools the planet by allowing heat to escape the atmosphere. The challenge for this technique is that cirrus clouds are in the region of the atmosphere where jets fly, which could make implementing this measure difficult.

Marine cloud brightening

This approach would add particles to low laying liquid clouds over the ocean to make them thicker and more reflective, which would cool the Earth, if it did not have side effects on other clouds. This mimics what happens now under certain conditions when ships spew pollution into the atmosphere. The effect only works for a few days, and sea salt could be sprayed up from the ocean to seed the clouds.

More information: Toni Feder, Should solar geoengineering be part of how humanity counters climate change?, *Physics Today* (2021). DOI: 10.1063/PT.3.4768

Yuanchao Fan et al, Solar geoengineering can alleviate climate change pressures on crop yields, *Nature Food* (2021). DOI: 10.1038/s43016-021-00278-w

Peter J. Irvine et al, An overview of the Earth system science of solar geoengineering, *WIREs Climate Change* (2016). DOI: 10.1002/wcc.423

Provided by Norwegian University of Science and Technology