Condensation nuclei help moist updrafts form towering storm clouds.SANTIAGO BORJA

Dehydrate the stratosphere to curb global warming?

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Given the alarm about rising levels of carbon dioxide and methane, it's easy to forget that plain old water vapor is a major greenhouse gas, too. It can linger for years in the stratosphere, for example, absorbing heat from the surface and re-emitting it back down. According to one study, a possible jump in stratospheric water during the 1990s may have boosted global warming by up to 30% during that time. But what if you could stop water from getting there in the first place?

That's the idea behind a new geoengineering technique, proposed today in *Science Advances*. By targeting rising, moist air and seeding it with cloud-forming particles right before it crosses into the stratosphere, geoengineers could cool the world with an intervention far more delicate than other schemes. Drying the stratosphere might take as little as 2 kilograms of material a week, says Shuka Schwarz, the study's lead author and a research physicist at the Chemical Sciences Lab of the National

Oceanic and Atmospheric Administration (NOAA). “That’s an amount of material that helps open the mind to imagine a whole bunch of possibilities.”

“Intentional stratospheric dehydration,” as it’s called, could only cool the climate moderately, offsetting roughly 1.4% of the warming caused by increased carbon dioxide over the past few hundred years. But for geoengineers who have talked about cooling the planet by loading the stratosphere with thousands of tons of reflective particles, “it’s clearly a new idea,” says Ulrike Lohmann, an atmospheric physicist at ETH Zürich. “This is something that could work.”

The scheme relies on a key fact: Only a few places in the world are hot enough to generate the powerful updrafts needed to lift air into the stratosphere, which begins between 9 and 17 kilometers above the surface, depending on latitude. The most important of these portals is found above the western equatorial Pacific Ocean, in a region roughly the size of Australia.

Along its upward journey, much of the water condenses into clouds and rains out of the air. But in the past decade, NASA used a high altitude, jet-powered drone to study the cold layers just below the stratosphere and found plenty of air masses moist enough to form clouds, but lacking in particles that would allow the moisture to condense into ice crystals and ultimately rain. “It’s a question of chance, whether they get to this coldest spot on their journey and there’s enough cloud nuclei left to do anything,” Schwarz says. The NASA studies also found that this moisture was concentrated: Just 1% of the air parcels explored accounted for half of the water that could end up in the stratosphere.

In a simple model, the team simulated injecting bismuth triiodide, a nontoxic compound that has been used in lab studies of ice nucleation, into the 1% areas most ripe for water harvesting. In an optimistic scenario, just 2 kilograms a week of seeds 10 nanometers in diameter would be

enough to convert those moist air parcels into clouds, they found. Such an amount could be sprayed by balloons or drones, with no airplane needed.

Daniel Cziczo, an atmospheric chemist at Purdue University, says the idea is interesting but could pose risks. If the seeds failed to form clouds in the right place and spread elsewhere, they could speed the formation of the wrong kinds of clouds: thin, wispy cirrus clouds, which reflect little sunlight but absorb infrared heat from the surface, Cziczo says. "You're basically exploring a technique that could have a warming effect and not a cooling effect."

Mark Schoeberl, an atmospheric scientist at the Science and Technology Corporation who previously identified the stratospheric gateway in the Pacific, agrees with the need for further study. "You want to avoid unintended consequences and make a clear-eyed assessment of implementation cost." The technique likely won't be effective all year round, he adds, because most water reaches the stratosphere during the Asian monsoon seasons. And just how much a reduction in stratospheric water would cool the surface is uncertain, he says.

Schwarz sat on the idea for a while, wary of the controversy that surrounds all proposals for tinkering with the planet to offset human-caused warming. But now that the U.S. Congress has mandated that NOAA study solar geoengineering, "the stigma around considering climate intervention is abating a bit," he says. "Two years ago, I for one would have really hesitated to consider these possibilities."

The openness is spreading. For example, the European Union is now supporting research into geoengineering governance. Switzerland last week called on the United Nations to support research in the area. And Lohmann's group last week won a grant from the Simons Foundation to study another intervention: thinning heat-trapping clouds above polar regions to mitigate warming.

“Things have changed on the science agenda,” Lohmann says. She says climate scientists have reservations about exploring these schemes but feel there is no choice. Emission cuts simply haven’t happened fast enough, and carbon dioxide cannot yet be sucked out of the air cheaply. “It’s clear we’re looking for something else,” she says. “It’s our failure as humans to avoid this.”

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