UC SANTA BARBARA

THE Current

September 17, 2025

Harrison Tasoff

A hard look at geoengineering reveals global risks

With CO_2 emissions continuing unabated, an increasing number of policymakers, scientists and environmentalists are considering geoengineering to avert a climate catastrophe. Such interventions could influence everything from rainfall to global food supplies, making the stakes enormous. In brief, manipulating other aspects of Earth's climate system might reduce some effects of climate change. But the wondrous complexity of our planet complicates every one of these proposals.

Climate scientists at UC Santa Barbara analyzed two approaches that involve reducing the amount of sunlight warming Earth's surface: cloud seeding over the eastern Pacific and introducing aerosols into the stratosphere. By modeling local effects on the Pacific Ocean, they found that the first strategy would completely disrupt one of the planet's major climate cycles, the El Niño Southern Oscillation. At the same time, the second would scarcely affect the system at all. The results, published in the journal Earth's Future, underscore the importance of considering the broad range of consequences that any geoengineering solution may have.

"We need to be careful about implementing geoengineering proposals before we fully understand what's going to happen," said first author Chen Xing, a doctoral student at UCSB's Bren School of Environmental Science & Management.

Xing and fellow Bren grad student Cali Pfleger were curious how geoengineering might impact marine ecosystems. But understanding this requires an account of their effects on the ocean's climate cycles, chief among them being the El Niño

Southern Oscillation (ENSO).

ENSO is a 2- to 7-year climate cycle that shifts the distribution of warm water in the tropical Pacific. This has profound implications for global weather patterns and atmospheric circulation. For instance, El Niño years bring warm waters to the west coasts of the Americas along the equator, causing wet winters in California. In contrast, South and Southeast Asia experience stronger monsoons when the western Pacific heats up in La Niña years.

The two geoengineering proposals the authors evaluated both involve releasing aerosols into the atmosphere; the difference is in what type, and how high up. Cloud seeding, or marine cloud brightening (MCB), involves injecting sea salt within 2 kilometers of the surface to promote more reflective cloud cover over the oceans. Meanwhile, stratospheric aerosol injection (SAI) blocks sunlight farther up by releasing sulfates high in the atmosphere.

Proponents of geoengineering have sometimes targeted the eastern sides of ocean basins (west coasts of the continents) for marine cloud brightening due to their strong effect on global temperature. Unfortunately, the southeastern Pacific in particular seems to have a large influence on ENSO. “Deploying MCB in the subtropical eastern Pacific dramatically reduces ENSO amplitude by approximately 61%,” the authors write.

“It’s hard to get ENSO to change by that much that quickly,” said Associate Professor Samantha Stevenson, who co-authored the study, and is Xing’s and Pfleger’s advisor.

Marine cloud brightening works by creating clouds with more numerous, but smaller droplets. The result is a more reflective cloud that keeps the surface underneath cooler. However, these smaller droplets inhibit raindrop formation, leading to drier conditions with less local rainfall. As this cool air moves into the central Pacific, it reduces the evaporation that drives atmospheric convection, further drying out the region. This cooling and drying of the eastern Pacific strengthens the winds along the equator. The result is drier, cooler, windier conditions in the sky with more upwelling and cooler surface temperatures in the sea. In other words, ENSO crashes.

The authors thought the proposals could have impacts, “but we didn’t expect two-thirds of ENSO’s variance to disappear,” Xing said. The implications seem clear:

“Don’t do MCB over the eastern Pacific Ocean because it might cause super strong chain reactions from ENSO’s disappearance.”

In contrast to the severe repercussions of marine cloud brightening, stratospheric aerosol injection had virtually no effect on ENSO. So why the difference?

The answer may have to do with altitude and the spatial distribution of cloud particles. MCB is more concentrated and closer to the surface, while SAI is carried out high in the atmosphere, where the particles are more dispersed. This means that SAI’s cooling influence is more evenly distributed and less disruptive to the tropical Pacific.

However, that doesn’t necessarily mean that all MCB strategies will have such a damaging impact on ENSO. According to Stevenson, these MCB simulations have such an impact because of the nature of this specific spot in the eastern Pacific. “We’re not saying that all MCB is going to kill ENSO. We’re just saying that this happens if you do it in this specific region,” she said. We could carry out marine cloud brightening elsewhere, she added, but we’d need a larger intervention to get the same amount of global cooling.

Of course, taking no action will also have consequences. Runaway climate change will certainly disrupt major natural cycles, ecosystems and social systems. As for ENSO, scientists currently don’t know what will happen to it. But that, itself, is reason for caution. “There’s nothing that compares to the speed with which ENSO would change in these MCB experiments,” Stevenson said. “It just does not naturally drop 60% in 10 years, even under climate change.”

Blocking sunlight from reaching Earth would also lower photosynthetic activity, decreasing the productivity of crops, forests and, crucially, marine algae. Algae form the foundation of the ocean food web and generate around 70% of oxygen in the atmosphere. The team plans to investigate the effects these proposals may have on marine ecosystems.

This study highlights the importance of understanding the nuances and tradeoffs when designing and choosing geoengineering solutions. “Two interventions can get to the same warming target globally and have extremely different regional climate impacts,” Stevenson said. “The most important question is, ‘Are we thinking of all of the potential consequences?’”

Tags
Climate Change

Media Contact
Harrison Tasoff
Science Writer
(805) 893-7220
harrisontasoff@ucsb.edu

About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.