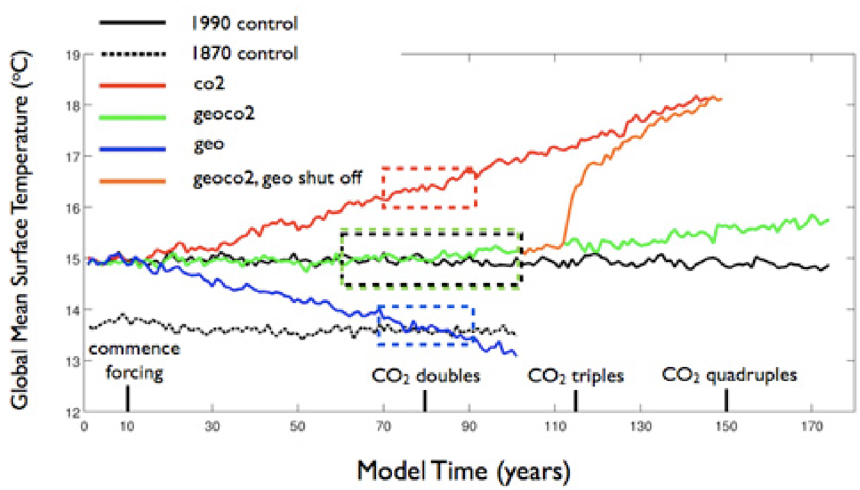
Man-Made Climate Change? Geoengineering Effects Explored

Simulations by University of Washington researchers outline potential risks and benefits of geoengineering



Time series of globally-averaged surface temperature for various simulations. The green line shows that as a sulfate layer is ramped along with carbon dioxide, global mean temperature can be held close to 1990 values. Additionally, the orange line illustrates the rapid rise in temperature that occurs if geoengineering with a sulfate layer is terminated, but carbon dioxide levels are still high.

Scientists suggest that our warming world may face catastrophic changes to the natural environment. Droughts, rising oceans, and fiercer and more frequent hurricanes are a few of the predicted outcomes.

Theoretically, it may be necessary for world governments to act to mitigate the damage. Initially, these efforts will probably take the form of limits on greenhouse gas emissions or forest preservation. But some scientists and policy makers believe it may be necessary to take an active hand in engineering a solution to our climate problems.

These potential solutions, collectively called “geoengineering,” would use scientists’ knowledge of the Earth’s cycles to curb the rise in temperature, the melting of the ice caps, and increasing weather volatility. Yet, very few scientific studies have tackled the practical implications of such extreme measures, in part because of the controversy surrounding the prospect of “messing with” the environment.

“It’s ground zero right now for understanding the climate response to geoengineering,” said Cecilia Bitz, associate professor of atmospheric sciences at the University of Washington (UW), and one of a handful of researchers in the U.S. exploring the impact of geoengineering ideas. “There’s only been a couple dozen papers in the literature, and you’ll be surprised to know that it’s a rarity to have an ocean GCM [general circulation model] in the model.”

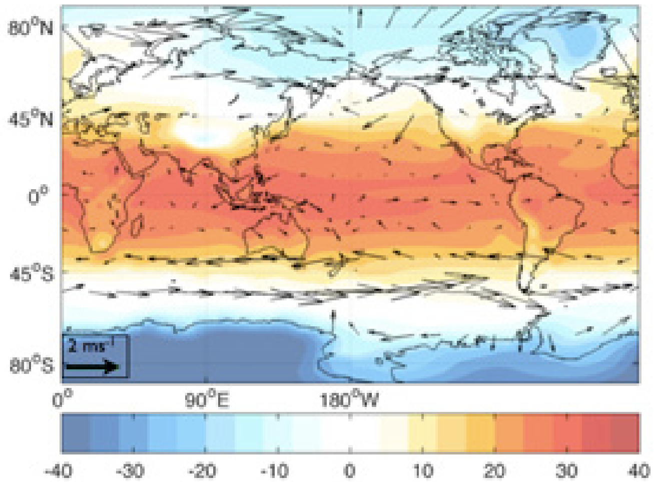
Working with Kelly McCusker, a graduate student, Bitz analyzed the impact of the leading geoengineering solution: the release of volcanic aerosols into the upper atmosphere — “the equivalent of Mount Pinatubo going off every year,” Bitz said, referring to the eruption in the Philippines in 1991 that was the largest in recent memory.

Hypothetically, these particles would reflect sunlight and reduce the amount that reaches the Earth’s surface. Bitz and McCusker, along with David Battisti, another professor at UW, simulated the interaction of these particles with the global climate using the Ranger supercomputer at the Texas Advanced Computing Center (TACC) to identify environmental changes that might accompany the release of massive amounts of aerosols into the stratosphere.

They found that, though it may be possible to reduce the atmospheric temperature, other aspects of climate change, specifically the melting of ice-caps which are linked to wind action and ocean currents, may be much more difficult to reverse.

“The effect of these particles is not perfect at all,” said McCusker. “There are regional issues, there’s still warming in the poles and subsurface ocean warming near ice sheets, and there are plenty of unknowns that we can’t answer.”

The study explicitly evaluates the role of ocean dynamics by comparing integrations with an atmosphere coupled to a full-depth ocean to integrations that have only a shallow mixed-layer ocean. This helps to better determine how a drastic man-made



In color is the annually averaged surface temperature over the planet, overlain with the change in winds at 850 millibars due to increased carbon dioxide and a stratospheric sulfate layer. The magnitude of these atmospheric circulation changes, especially over the Southern Ocean, is similar to that induced by just an increase in carbon dioxide.

change might interrupt the Earth's linked environmental systems. The work follows up on other atmospheric studies by Bitz, including a recent publication in Nature that suggests that Greenhouse gas mitigation can reduce sea-ice loss and increase polar bear persistence.

With their geoengineering simulations, Bitz and McCusker are looking at 21st century scenarios, where the world ramps up CO2 very quickly in the early half of the century, and the climate starts deteriorating in ways that society considers unacceptable.

"We don't know what society would consider an unacceptable level of climate change, but it may happen and at that point there may be a demand to geoengineer," Bitz said.

According to Bitz, much of the dynamic changes in the ocean from creating excessive amounts of carbon-dioxide are still present in the geoengineered world. That's not necessarily a good thing, because these changes are very large in some places and slow to disperse. In the Southern Ocean, for instance, CO2 levels may be affecting the ocean heat transport toward the icecaps and precipitating sea level rise, which would not be overcome by the release of aerosols.

"If it's sea level rise driven by ice shelf melting in the Antarctic that is of concern, and it is a consequence of ocean circulation changes instead of actual warming, geoengineering may not help," Bitz said. "Those are the type of questions we're trying to address."

The challenge of studying geoengineering is the lack of a physical suitable environment for experimentation.

"We only have one planet," said Alan Robock, associate director of the Center for Environmental Prediction in the department of environmental sciences at Rutgers University, and a leading geoengineering researcher. "Meteorologists and climate scientists do not have laboratories with test tubes or accelerators. And we cannot mess with the only planet we have to test its responses to making stratospheric clouds or brighter oceanic clouds, so we use models of the climate system - computer simulations of how the climate would respond to these forcings. We test these models by simulating the past, including the effects of volcanic eruptions and ship tracks, and then we use them to investigate the response to many different scenarios."

Bitz and McCusker outlined the changes that a range of geoengineering implementations may incur. (The simulations only modeled reductions in solar input, not the removal of carbon dioxide or other geoengineering solutions.) One extreme scenario involved modeling the changes that would occur if the world began to use geoengineering and then stopped abruptly [see graph and description at top]. Such a case would lead to dangerously rapid warming. Other implementations included steady, or slowly increasing, releases of the aerosols, which lead to different effects.

"These ideas have been around for 30 years, maybe more, but there is hesitation among researchers because sometimes people argue, still, that you're supporting geoengineering, or allowing it to happen, by doing research," said Bitz. "I don't believe that, because people would possibly do it without knowing the consequences."

Cecilia Bitz (right), associate professor of atmospheric sciences at the University of Washington, and Kelly McCusker, a graduate student at UW.

Bitz hopes the solutions that she's exploring will never be tested. But, like an evacuation plan or a bomb shelter, it is comforting to know that if solutions are required, scientists have initial research and a sense of potential outcomes.

Said Robock, "We may discover dangerous consequences we never thought of before. Or we may find that particular geoengineering scenarios reduce the risk of global warming more than the additional risks they present. This will allow us to make an informed decision some time in the future when we are faced with dangerous climate change."

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