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Big fixes for climate?

Scientists take a fresh look at geoengineering

by Bob Henson

Had Charles Dudley Warner been writing in 2006 rather than a century earlier, he might have aimed his famous gripe about weather at global-change researchers instead: "Everybody talks about the climate, but nobody does anything about it." In one sense, that isn't true: humans have been inadvertently modifying climate for many years—most dramatically by adding greenhouse gases to the atmosphere, warming the planet by as much as 0.8°C (1.4°F) since Warner's time. But in another sense, the quote would be correct: few scientists have been willing to look at schemes to reduce the potential for catastrophic change . . . until recently.

Based on the well-documented climatic effects from the eruption of Mt. Pinatubo in 1991, some scientists are exploring how human injections of sulfates into the stratosphere could help cool the climate artificially. (Image courtesy U.S. Geological Survey.)

Research into geoengineering, as these schemes are commonly known, has been going on for decades (see "On the Web") but has generally kept a low profile. Researchers have feared that writing or saying anything on the topic would send a tacit message that global warming can't be reined in through emissions cuts alone. However, an increasing number of scientists believe that we are transforming our energy system far too slowly to avoid the risk of a catastrophe. Some of these scientists are now looking more thoroughly at geoengineering techniques that might be deployed if the situation becomes dire enough. Even with some consequences poorly understood—and others yet to be identified—the new studies are attempting to lay out the pros and cons of geoengineering in more detail than previous research.

Though many geoengineering proposals have been floated at conferences and in the media over the last few years, little analysis has been published in peer-reviewed journals. This relative lack was turned around in August with a set of papers in the journal *Climatic Change*, including one by Nobel Prize winner Paul Crutzen (Max Planck Institute for Chemistry). At least two other analyses of geoengineering techniques appeared in major journals this autumn, and a landmark invitation-only workshop on 18–19 November, sponsored by NASA and the Carnegie Institution, pulled together more than 40 scientists for a frank discussion of how humans might "manage" solar radiation and whether or not this is even advisable.

"The goal was to educate ourselves about the various proposals, identify important technical and scientific questions, and come up with steps for moving a research program forward," says workshop chair Ken Caldeira (Stanford University). "We had many bright people on hand with a lot of knowledge and good ideas." A report on the meeting should be out by January, he says.

A dormant topic catches fire

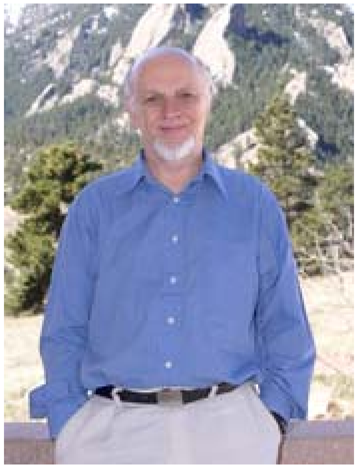
Stanford's Ken Caldeira chaired a recent workshop on geoengineering. (Photo courtesy Ken Caldeira.)

The most widely publicized geoengineering approach of the 1990s—sprinkling iron over the ocean to stimulate the growth of phytoplankton that would draw CO_2 from the atmosphere—reached the point of small-scale field tests, but these fell short of expectations. Crutzen's approach builds on the planet-wide episodes of cooling that followed the eruptions of El Chichón (1982) and Mt. Pinatubo (1991). Given the fairly well-known effects of these volcanoes, Crutzen analyzed the option of repeatedly injecting large amounts of sulfate aerosol into the stratosphere, an idea suggested in the 1970s by Russian scientist Mikhail Budyko. Each infusion of particles would shield sunlight and cool global climate for a year or two, just as a massive volcanic eruption would, although it wouldn't alleviate the impact of increased atmospheric carbon on oceans and other ecosystems. The injections would have to continue as long as greenhouse gas emissions remained elevated.

"If sizeable reductions in greenhouse gas emissions will not happen and temperatures rise rapidly, then climatic engineering . . . is the only option available to rapidly reduce temperature rises and counteract other climatic effects," writes Crutzen. He stresses that the technique would be a last-ditch option that "should not be used to justify inadequate climate policies."

The decision to publish Crutzen's work was not a straightforward one, according to Ralph Cicerone, president of the National Academy of Sciences. Cicerone consulted with *Climatic Change* editor Stephen Schneider (Stanford University) and wrote an accompanying editorial. "Various individuals have opposed the publication of Crutzen's paper, even after peer review and revisions, for various and sincere reasons that are not wholly scientific," writes Cicerone in his editorial.

NCAR scientists are using global models to flesh out Crutzen's idea. NCAR's Tom Wigley published a paper in *Science* on 14 September showing how sulfate injections in the stratosphere might be combined with emissions cuts in a staged fashion that could yield better results than either approach separately. Using an energy-balance model that calculates global average temperature but not regional effects, Wigley found that injecting a Pinatubo-sized batch of sulfates into the stratosphere every one to four years could buy up to 20 years before major cutbacks in emissions would be required.



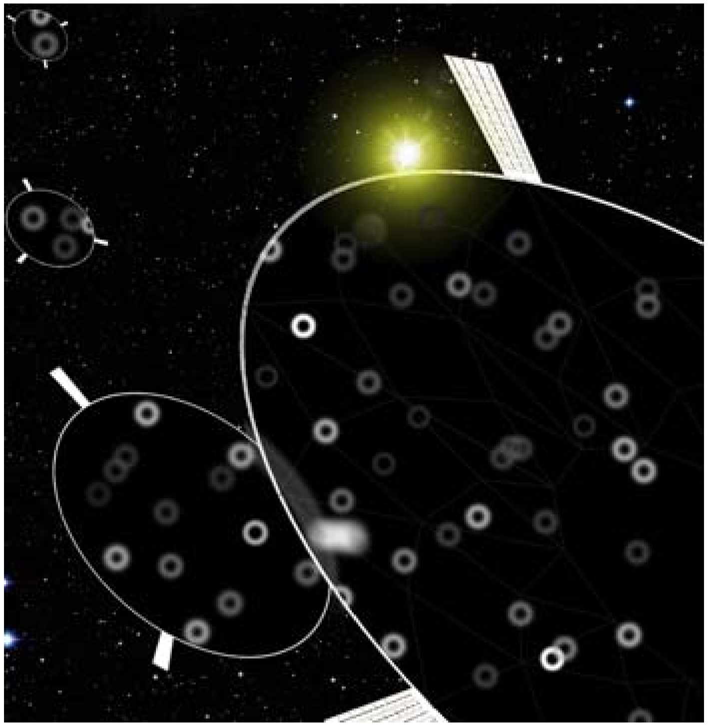
Tom Wigley. (Photo by Carlye Calvin.)

"We're already performing an uncontrolled experiment. We don't really know what the consequences are going to be," says Wigley. "We shouldn't rule anything out at this stage. We need to investigate all the options in an honest and comprehensive way."

Going a step further, NCAR's Philip Rasch has been using the NCAR Community Atmosphere Model to analyze the regional and seasonal fingerprints that stratospheric injections might leave on climate. In work yet to be published, Rasch is finding that even if global temperature could be stabilized, high-latitude winters might still warm up. Rasch's modeling also shows that geoengineering could affect rainfall patterns in the tropics and Southern Ocean.

"We have a long way to go," says Rasch of the effort to model stratospheric injections more precisely. "How would the injection really manifest itself in aerosol formation—would the aerosols be the same size as those from volcanoes? How would the sulfates affect cirrus clouds? There are also many, many unanswered questions on how feasible this entire approach would be."

In an article that accompanies Crutzen's essay in *Climatic Change*, NCAR's Jeffrey Kiehl expresses support for open dialogue and study of geoengineering but adds, "I feel that treating the cause(s) rather than the symptom is the more appropriate approach to the problem." He also warns against taking model results too literally: "When will we know a model is 'good enough' to go out and perform a real experiment?"



Above are a few of the 16 trillion sunlight-refracting shades proposed for deployment. Each mirror would span less than a square meter. The use of refraction rather than reflection would diminish sunlight-induced pressure from that would otherwise shift the shades' orbit. (Image courtesy of Roger Angel, UA Steward Observatory.)

The unanswered questions in geoengineering, and the possible side effects, trouble Alan Robock (Rutgers University). He's concerned about ocean acidification, ozone loss, and other problems that could emerge or intensify due to sulfate injections. Despite his qualms, Robock, who has long studied the atmospheric impact of volcanic eruptions, is now examining how geoengineering might tweak the atmosphere. "I think research is a good idea, but I think we have to try and look at all the possible consequences," says Robock. "There are things we're not smart enough to know about right now."

Based on how other kinds of aerosols affect the sky, geoengineering could change even the aesthetics and the psychological impact of the sky, notes Robock. "We'd have less blue skies overall," he says, "but nice sunsets."

Other ways to block the Sun

John Latham. (Photo by Carlye Calvin.)

Artificial eruptions aren't the only ideas on the table for modulating solar radiation. For more than a decade, NCAR's John Latham has been pondering how humans might change the character of marine stratocumulus clouds. His idea, which he first raised in 1990 in the journal *Nature*, was evaluated numerically this year by Keith Bower (University of Manchester) and colleagues in a paper Marine stratocumulus, which cover much of the subtropical ocean, are among Earth's most reflective clouds. If the number of droplets in these clouds could be increased by about 10%, Latham argues, the clouds' enhanced reflectivity might be enough to counteract even a doubling of carbon dioxide.

One method for doing this, under study by Stephen Salter (University of Edinburgh), would be to use 20-meter-high rotors aboard seagoing vessels to generate saltwater spray that could serve as cloud nuclei (see illustration). Rough calculations indicate that to counteract a doubling of present-day concentrations of carbon dioxide, about 50 cubic meters of ocean water would need to be sprayed globally every second, according to Latham.

"Our recent papers, and positive responses to a lot of seminars and conference presentations, have now given us much more confidence and affirmation," says Latham. As with other climate engineering proposals, he adds, the possible side effects on regional climate would have to be studied carefully.

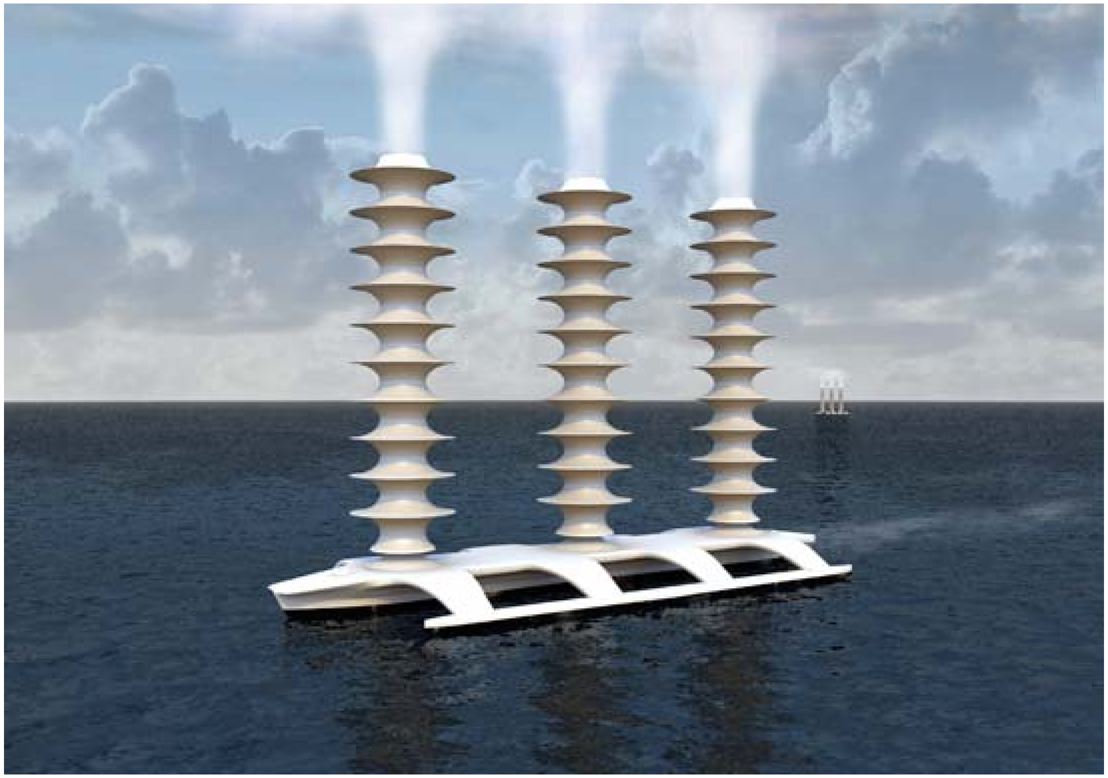
Yet another technique was described by Roger Angel (University of Arizona) in the 3 November issue of the *Proceedings of the National Academies of Science*. This idea involves a set of 16 trillion transparent, sunlight-refracting shades that would be deployed at the inner Lagrangian point of gravitational balance, about 1.5 million km from Earth toward the Sun. Though each shade would weigh only about a gram and cover roughly the area of a broadsheet newspaper page, the project's scale would still be gargantuan: 20 launchers would each need to loft 800,000 screens every five minutes for ten years.

All told, Angel says, his scheme would cost a few trillion dollars over about 25 years. As with other geoengineering ideas, that cost seems staggering, but it pales compared with the estimated cost of global warming that was recently produced for the British government by economist Nicholas Stern: 5–20% of the global economy over the next century.

Ralph Cicerone. (Courtesy National Academies.)

In his *Climatic Change* editorial, Cicerone offers some thoughts on how the increasing flow of research into geoengineering might be channeled. Given the risk that countries might act independently to tamp down global warming, Cicerone calls for scientists to consider a moratorium on large-scale field tests until some sort of scientific and public review process can be assembled.

Cicerone also notes that many people have great faith in technology, while others are frightened by it. "Plans for geoengineering will require both of these groups to listen and perhaps to agree on proper actions," writes Cicerone, "while research on geoengineering should proceed independently."



This artist's conception shows a

proposed device for lofting large quantities of seawater spray into the atmosphere to help boost the sun-reflecting power of marine stratocumulus clouds. (Illustration courtesy John MacNeill.)

On the Web

Geoengineering history (IPCC Third Assessment Report, 2001)

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