ATMOSPHERIC SCIENCE

Pollute the Planet for Climate's Sake?

The source of the proposal was almost as remarkable as the idea itself. In the August issue of *Climatic Change*, Paul Crutzen, who won the Nobel Prize for helping work out the chemistry of ozone destruction in the stratosphere, resurrected an oft-disparaged suggestion: Create a global haze by spewing megatons of sulfurous debris into the stratosphere to shade the planet and rein in greenhouse warming. "A few years ago, I would have said, 'I'm not touching that,'" says the Max Planck Institute for Chemistry researcher. Now, however, he finds the "grossly disappointing international political response" to global warming's threat so disturbing that the notion of deliberately contaminating the stratosphere looks less and less crazy.

Bad idea, respond some climate scientists. It would be applying a Band-Aid to the symptom while continuing to stoke the problem with ever-increasing greenhouse gas emissions. Best not even to talk about it. Worth looking at, say others. Given the surprises that may be lurking in the greenhouse, desperate countermeasures could come in handy. Thanks to Crutzen's stature, this scientific and ethical debate is blossoming as the climate community begins to take a hard look at geoengineering climate.

A volcanic chill. Humans might loft sulfur into the stratosphere to counteract global warming; Mount Pinatubo did in 1991.

CREDIT: BULLIT MARQUEZ/AP PHOTO

Supporters of at least studying the idea seem to have some momentum for now. "Crutzen's paper created some sort of phase change, making geoengineering a respectable topic of conversation," says climate modeler Kenneth Caldeira of the Carnegie Institution Department of Global Ecology at Stanford University.

Geoengineering as a fix for global warming has been a topic of usually sotto voce conversation since the 1970s, when the Soviet climatologist Mikhail Budyko suggested Earth could be cooled by adding tiny sunlight-reflecting particles to the stratosphere. Nature soon served up a couple of striking examples of how it might be done when the volcano El Chichón erupted in 1982 and Mount Pinatubo erupted in 1991. The long-lived stratospheric debris of Pinatubo—water droplets laced with sulfuric acid derived from the volcano's sulfur—reflected enough sunlight back into space to cool Earth on average 0.5°C for a year or two following the eruption. That's about the size of the warming of the past century.

Pulling off a "human volcano" to counteract global warming would take some wherewithal. Pinatubo put up 10 million tons of sulfur, most of which fell out of the stratosphere within 2 or 3 years. So humans looking to cool the greenhouse by stratospheric shading would have to send millions of tons of sulfur tens of kilometers into the air every year, perhaps century after century, in order to renew the continually depleted shield of haze. The resulting acid rain would be minor compared to current levels, say proponents.

People have discussed delivery methods from balloons, big guns, and giant planes. To ease the burden of lifting megaton masses, the late Edward Teller—father of the hydrogen bomb and "Star Wars" missile defense advocate—proposed substituting more efficient reflectors for sulfur, something metallic and perhaps engineered like tiny retroreflectors. ▶

Pass the Hat for Alien-Hunting

With NASA scaling back funding for astrobiology, scientists are turning to California's Silicon Valley to keep hope alive. The SETI Institute in Mountain View, whose more than two dozen researchers rely on NASA astrobiology grants, plans to create a new privately funded center devoted to the study of life in space. Organizers are looking for up to $6 million over the next 3 years, says SETI's Scott Hubbard, with funds aimed at retaining staff and expanding research at the newly named Carl Sagan Center. The community took a similar approach after lawmakers refused to fund extraterrestrial intelligence research a decade ago.

–ANDREW LAWLER

Crawford Pleads Guilty

A former head of the U.S. Food and Drug Administration (FDA) pleaded guilty this week to owning shares of stock in companies the agency regulates and filing false financial disclosure forms saying he had sold them. Lester Crawford, a pharmacologist and veterinary medicine specialist who resigned his post suddenly last fall after just 2 months, was charged with two misdemeanors for withholding financial information. The Justice Department complaint states that Crawford, who spent 8 years at FDA in three separate stints, or his wife owned shares in soft-drink maker Pepsico while he chaired an FDA obesity working group.

"There's little that we can do if people do not provide honest disclosures of financial interest," says Jeremy Sugarman, a bioethicist at Johns Hopkins University in Baltimore, Maryland. Sentencing is set for January.

–JENNIFER COUZIN

Biosafety Lab Delayed

A U.S. nuclear-weapons lab must conduct another environmental review before opening a biosafety level 3 lab on its grounds, a federal appeals court ruled this week. The move is a win for activists led by the Livermore, California, based Tri-Valley Cares, which had sued the Department of Energy's Lawrence Livermore National Laboratory over the proposed facility in 2003. Such a review, which must consider the possibility of a terrorist attack on the lab, could take a year. Livermore says it is mulling its options; activists hope the decision will bolster efforts to thwart other planned biosafety labs at government facilities. Livermore had planned to open the lab as soon as next month (*Science*, 13 October, p. 235).

–ELI KINTISCH

Published by AAAS

Daunting practical aspects aside, the latest—although preliminary—climate modeling hints that shading the globe to counteract greenhouse warming could actually work. In this issue of *Science* (p. 452), climate researcher Tom Wigley of the National Center for Atmospheric Research in Boulder, Colorado, reports that in a simple, so-called energy-balance model, firing off a Pinatubo eruption every 2 years or so would be enough to counteract the projected warming indefinitely. And so far in sophisticated general circulation models (GCMs), "all the simulations have suggested it would basically work," says Caldeira, who has run many such simulations. Crutzen, who has been cooperating on other GCM simulations, agrees. "It's very tantalizing," he says. "It just looks too good."

That's what worries many climate researchers. "I refuse to go down that road," says biogeochemist Meinrat Andreae of the Max Planck Institute for Chemistry in Mainz, Germany. "You're papering over the problem so people can keep inflicting damage on the climate system without having to give up fossil fuels." That option could be so attractive that "the biggest risk of geoengineering is it eliminates pressure to decrease greenhouse gas emissions," says Caldeira.

Other critics note that if a shading effort faltered, decades or centuries of greenhouse warming would envelop the world in a couple of years. Nonclimate effects of carbon dioxide, such as acidification of the oceans, would continue apace despite the shading. And then there's the complexity of the climate system. Recent model simulations aside, "we don't know exactly what is going to happen" once stratospheric shading begins, says climate modeler Lennart Bengtsson of the Max Planck Institute for Meteorology in Hamburg. All things considered, many climate scientists would just as soon see geoengineering of the climate problem returned to obscurity.

Ignoring the idea has its appeal, admits climate modeler Michael MacCracken of the Climate Institute in Washington, D.C., but "the question comes up so many times, you have to be addressing it." And studying the possibility wouldn't mean it would have to be done, says geoscientist Michael Oppenheimer of Princeton University. Quite the opposite. The idea of sucking the greenhouse's carbon dioxide into the deep sea by fertilizing ocean phytoplankton with iron only went away, he notes, after small-scale experiments showed it wouldn't work as proponents hoped (*Science*, 11 August 1995, p. 759).

A human volcano has obvious drawbacks, concedes Ralph Cicerone, an atmospheric scientist and president of the U.S. National Academy of Sciences, but they may appear to dwindle in the future. If warming took off far faster than expected, for example, and serious efforts to cut back greenhouse gas emissions were failing, a stopgap approach would become more attractive, he says. A scientific understanding of the shading option should be in hand in case that happens, he argues; scientists could study geoengineering while agreeing not to carry it out on a large scale. The U.S. Department of Energy seems to agree. Officials there, emboldened by Crutzen's paper, are taking a renewed interest in stratospheric shading, arranging workshops and a meeting next year while considering releasing a report on the subject.

–RICHARD A. KERR

PHYSICS

Voilà! Cloak of Invisibility Unveiled

Just 5 months after predicting it should be possible, a team of physicists has produced a cloaking device that renders an object invisible—at least when viewed in microwaves of a particular wavelength.

The cloak is hardly perfect: Instead of an all-concealing sphere, it's a ring that works only for microwaves zipping along in a plane. The microwaves must also be polarized perpendicular to the plane. And even then, the cloak reflects some of the waves and casts a slight shadow. Nevertheless, "it's a very good achievement," says Ulf Leonhardt, a theorist at the University of St. Andrews in the United Kingdom. "It's surprising that it's as simple as it is and that it works so well."

The cloak embodies the theory laid out by theorist John Pendry of Imperial College London and experimenters David Schurig and David Smith, who work in the electrical and computer engineering department at Duke University in Durham, North Carolina. In May, the team showed that, in principle, it's possible to ferry electromagnetic waves such as light around an object by surrounding it with a "metamaterial": an assemblage of tiny rods and C-shaped rings (*Science*, 26 May, p. 1120). The waves would then pass as if the object weren't there, rendering it invisible.

The electromagnetic waves cause the electrons in the rings and rods to slosh, and the sloshing, in turn, affects the speed at which the waves travel through the material. If the speed varies in the right way within the cloak, the waves will curve around the object. The theory predicts only how the speed of the waves must vary; it leaves it to experimenters to design the material.

Where'd it go? This cloaking device is practically invisible—if you see the world in microwaves with a wavelength of 3.5 centimeters.

CREDIT: DAVID SCHURIG

When Schurig, Smith, and colleagues worked out the details, they found that their two-dimensional device required only C-shaped copper rings nestled side by side. The team also simplified the parameters specified by the theory. The changes made the metamaterial easier to build but also left the cloak slightly reflective, as the team reports online this week in *Science* (www.sciencemag.org/cgi/content/abstract/1133628). "The goal of this paper was to demonstrate that we more or less have the mechanism and that we can design the materials to the parameters," Schurig says.

Even the simplified cloak is a significant advance, says Costas Soukoulis, a theorist at Iowa State University in Ames and the U.S. Department of Energy's Ames Laboratory. "This is very, very important that experiments have produced what theorists had predicted," Soukoulis says. Microwave cloaks might be useful for eluding radar, he says.

It may take years for researchers to make a cloak for visible light. Still, most believe such a thing should be possible now that a cloak for microwaves has been built. After all, not seeing is believing. **–ADRIAN CHO**

Published by AAAS