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GLOBAL WARMING

Desperate Cooling Measure Is Aired

Artificial injections of sulfur into the stratosphere would cool Earth, scientist suggests

Ivan Amato

The world might need to radically combat global warming by deliberately injecting a small volcanic eruption's worth of planet-cooling sulfur into the stratosphere. That's the talked-about proposal being set forth in a controversial essay by Nobel Prize-winning chemist [Paul J. Crutzen](#), which appears in the August issue of the journal *Climatic Change* (DOI: 10.1007/s10584-006-9101-y).



S. Geological Service

Natural Coolant Sulfur from volcanic eruptions such as this one of Mount Pinatubo leads to atmospheric aerosols that cool the planet.

The journal's editor, climatologist Stephen H. Schneider of Stanford University, says scientists and politicians "must study the potential" of geoengineering-based strategies such as the global-scale cooling experiment that Crutzen, of Max Planck Institute for Chemistry, in Mainz, Germany, outlines in his essay. However, Schneider stresses that considering such drastic measures to mitigate global warming should in no way reduce a sense of urgency for safer solutions, including more energy-frugal lifestyles and helping the developing world leapfrog over the carbon dioxide-emitting adventure of the Industrial Revolution.

In his essay, Crutzen explains that global warming from the buildup of carbon dioxide and other greenhouse gases is partially countered by a cooling effect due to backscattering of sunlight by aerosols that form from sulfate

particles. In this way, even the sulfurous pollution that has caused acid rain, now on a decline, has had a cooling effect.

The 1991 eruption of Mount Pinatubo in the Philippines provides a dramatic natural example of the power of aerosol cooling. Six months after the eruption, Crutzen notes, about 6 billion kg of sulfur (from the volcano's initial injection of 10 billion kg) in the form of aerosol-forming sulfate remained in the stratosphere. The result of this event was a 0.5 °C cooling at Earth's surface in the year following the eruption.



COURTESY
OF PAUL CRUTZEN
Crutzen

It would take about 5.3 billion kg of sulfur introduced into the stratosphere per year to compensate for a doubling of atmospheric carbon dioxide levels, Crutzen says. Increasing the amount of sulfate aerosols "can be achieved by burning S₂ or [by] H₂S carried into the stratosphere on balloons and by artillery guns to produce SO₂," he suggests in his essay. Perhaps a chemist could develop a sulfur-containing gas that is stable lower in the atmosphere, where it would be easier to place, but which then would undergo a reaction in the stratosphere to produce SO₂ or another sulfur-containing gas that can produce aerosol-forming H₂SO₄, Crutzen asks as a prod to his chemist colleagues.

Crutzen describes his climate engineering proposal as a last-resort hedge on what he fears will become a too-little-too-late response to global warming. "I am only in favor of doing the manipulation if there are no severe side effects and the climate is running away," Crutzen tells C&EN. For now, he says, "I recommend research."

In recognition of the controversial nature of Crutzen's ideas, *Climatic Change* commissioned a half-dozen articles to help readers develop a fuller perspective of the pros, cons, and uncertainties, Schneider says.

Climate modeler Gavin Schmidt of NASA's [Goddard Institute for Space Studies](#) in New York City views Crutzen's essay as a strong but prudent call to other scientists to engage in "what if" scenarios, including the worst cases. "I am not as pessimistic as Crutzen," Gavin says. There's a chance the world will take steps that will make geoengineering experiments unnecessary, he says, a result that Crutzen rates as "a pious wish."

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