

Geoengineering to Shade Earth

Ken Caldeira

In June 1991, Mount Pinatubo in the Philippines erupted explosively—the biggest eruption of the twentieth century. The volcano created a column of ash and debris extending upward 40 kilometers (about 25 miles). The eruption ejected around 20 million tons of sulfur dioxide into the stratosphere, where it oxidized to form sulfate dust particles. The stratosphere is the part of the atmosphere that is higher than where jets normally fly.¹

As a result, about 2 percent of the sunlight passing down through the stratosphere was deflected upward and back into space. The dust particles were big enough to scatter sunlight away from Earth but small enough to allow Earth's radiant heat energy to escape into space. Earth cooled about half a degree Celsius (almost 1 degree Fahrenheit) the following year, despite the continued increase in greenhouse gas concentrations. This raises an obvious question: Could we similarly put dust into the stratosphere to offset climate change?²

Earth is heated by sunlight and cooled by the escape of radiant heat into space. Earth's atmosphere is relatively transparent in the wavelengths that make up sunlight but somewhat opaque in the wavelengths that make up escaping radiant heat energy. As greenhouse gases accumulate, the atmosphere becomes more opaque to out-

going radiant heat. With greater amounts of radiant heat trapped in the lower atmosphere, Earth's surface warms.³

The most obvious approach to keeping Earth cool is to reduce greenhouse gas concentrations in the atmosphere, so that heat energy can escape more easily into space. But another strategy involves reducing the amount of sunlight absorbed by Earth. If greenhouse gases accumulating in the atmosphere are like closing the windows of a greenhouse and trapping heat inside, then "geoengineering" approaches seek to keep Earth cool by putting the greenhouse partially in the shade. They try to reverse warming by preventing sunlight from being absorbed by Earth.⁴

A number of modeling and theoretical studies have looked into such climate engineering schemes. The consensus appears to be that these will not perfectly reverse the climate effects of increased greenhouse gases but that it might be technically feasible to use geoengineering to reduce the overall amount of climate change. Obviously, however, these schemes would not reverse the chemical effects of increased carbon dioxide (CO₂) in the environment, such as ocean acidification or the CO₂-fertilization of land plants.⁵

Several approaches have been suggested for deflecting sunlight away from Earth. The most science-fiction scheme would be to place sunlight-blocking satellites between Earth and the sun. But in order to compen-

Ken Caldeira is a climate scientist at the Department of Global Ecology at the Carnegie Institution for Science in Stanford, California.

sate for the current rate of increases of greenhouse gases in the atmosphere, governments would need to build and put in place more than a square mile (about 3 square kilometers) of satellite every hour. Most people would probably agree that such an enormous effort would be better applied to reducing greenhouse gas emissions.⁶

The placement of sulfur dust particles in the stratosphere appears to be the leading candidate for most easily engineering Earth's climate. (Numerous other approaches have been suggested, including some designed to increase the whiteness of clouds over the ocean with sea salt particles formed by spraying seawater in the lower atmosphere.) Tiny particles have a lot of surface area, so a lot of sunlight can be scattered with a relatively small amount of dust. The full amount of sulfur from Mount Pinatubo, if it had remained in the stratosphere for a long time, would have been more than enough to offset the warming (at least, on a global average) from a doubling of atmospheric carbon dioxide content. The actual short-lived cooling from the Mount Pinatubo eruption turned out to be much less because the oceans helped keep Earth warm despite the reduction in the amount of absorbed sunlight.⁷

The sulfur from Mount Pinatubo remained in the stratosphere only for a year or two. To maintain a dust shield in the stratosphere for the long term would require continual dust injection. It is thought that a small fleet of planes, or perhaps a single fire hose to the sky suspended by balloons, would be enough to keep the dust shield in place. Costs are uncertain, but it might total less than a few billion dollars a year. The amount of sulfur required would be a few percent of what is currently emitted from power plants and so would contribute somewhat to the acid rain problem.⁸

Why might policymakers want to deploy



Karin Jackson, U.S. Air Force

Mount Pinatubo erupting on June 12, 1991, as seen from Clark Air Force base eight miles away

climate engineering systems? The main reason is to reduce climate damage and the risk of further damage from greenhouse gases. Some commentators deny the reality of human-caused greenhouse warming but think it worth developing climate engineering systems as an insurance policy—just in case events prove them wrong. Others accept human-induced climate change but think reducing emissions will be either too costly or too difficult to achieve, so they favor climate engineering as an alternative approach. Some people fear that a climate crisis may be imminent or already unfolding and that these systems are needed right away to reduce negative climate impacts such as the loss of Arctic ecosystems while the world works to reduce greenhouse gas

emissions in the longer term. Still others think climate engineering is needed as an emergency response system in case an unexpected climate emergency occurs while greenhouse gases are being reduced.⁹

There are also many reasons not to develop climate engineering, some of them having to do with climate science and some having to do with social systems. These schemes will not work perfectly, for example, and there is some chance that unanticipated consequences will prove even more environmentally damaging than the problems they are designed to solve. Concerns include possible effects on the ozone layer or patterns of precipitation and evaporation. Climate engineering would not solve the ocean acidification problem, although it would not directly make it worse either.¹⁰

Some observers fear that the mere perception that there is an engineering fix to the climate problem will reduce the amount of effort placed on emissions reduction. Climate engineering could lull people into complacency and produce even greater emissions and ultimately greater climate damage. (On the other hand, such schemes also could frighten people into redoubling

efforts to reduce greenhouse gas emissions.) And it might work well at first, with negative consequences manifesting themselves strongly only as greenhouse gas concentrations and the offsetting climate engineering effort both continued to grow.¹¹

Climate engineering will affect everyone on the planet, but there is no clear way to develop an international consensus on whether it should be attempted and, if so, how and when. It would likely produce winners and losers and therefore has the potential to generate both political friction and legal liability. Conflict over deployment could produce political strife and social turmoil. (On the other hand, any success at reducing climate damage could lessen strife and turmoil.)

From the perspective of physical science and technology, it appears that climate engineering schemes have the potential to lower but not eliminate the risk of climate damage from greenhouse gas emissions, yet unanticipated effects and difficult-to-predict political and social responses could mean increased risk. Thus the bottom line is that climate engineering schemes have the potential to make things better, but they could also make things worse.

2 0 0 9

STATE OF THE WORLD

Into a Warming World

To purchase the complete *State of the World 2009* report
with endnotes and resources, please visit
www.worldwatch.org/stateoftheworld.

To purchase bulk copies, contact Patricia Shyne at 202-452-1992,
ext. 520, or pshyne@worldwatch.org.

