Volcanoes Can Muddle the Greenhouse

Cleaning up climate records reveals that the largest volcanic eruptions cool the climate for a few years, complicating identification of the greenhouse warming; climate disasters loom too

AS SCIENTISTS AND POLITICIANS anxiously eye signs of global greenhouse warming, climatologists are finding the best evidence yet that a massive volcanic eruption can temporarily bring the mercury down a notch or two. Such a cooling could be enough to set the current global warming back more than a decade, confusing any efforts to link it to the greenhouse effect.

By effectively eliminating some nonvolcanic climate changes from the messy record of the past 100 years, researchers have detected drops in global temperature of several tenths of a degree within 1 to 2 years of volcanic eruptions. Apparently, the debris spewed into the stratosphere blocked sunlight and caused the temperature drops. Climatologist James Angell, who a few years ago could find little evidence that volcanic eruptions caused global cooling, is impressed by the new work: "a pretty good assessment" is how he describes it.

For all their potential social significance, the climatic effects of volcanoes have been hard to detect. The problem has been identifying a volcanic cooling among the nearly continuous warmings and coolings of a similar size that fill the climate record.

The solution seems to be in cleaning up the climate record by removing the temperature variations caused by any known, nonvolcanic causes. Meteorologists Clifford Mass of the University of Washington and David Portman of Atmospheric and Environmental Research, Inc., in Cambridge, who was a student of Mass's, recently took that approach by correcting for the effect of the El Niño cycle. El Niño's abnormally warm waters in the equatorial Pacific tend to warm the atmosphere, just as the abnormally cold waters of the other half of the cycle, called La Niña, cool the atmosphere.

When Mass and Portman adjusted the temperature record for the effect of the El Niño cycle, they found that the five larger eruptions of the nine they studied cooled the hemisphere by 0.1° to 0.5°C, while the four smaller events produced little or no temperature signal. (For comparison, the sizzling 1980s are some 0.34°C warmer than earlier decades.) The largest climate effect followed the massive eruption of Krakatau in 1883, with a temperature drop of 0.5°C. On average, the five largest eruptions dipped the hemispheric temperature about 0.3°C for 2 to 3 years, in line with theoretical predictions.

"I think it's obvious that what's been screwing us up has been El Niño," comments Angell, who tracks climate trends for the National Oceanic and Atmospheric Administration in Silver Spring, Maryland. He had done his own El Niño cycle correction while Mass and Portman were working on theirs and found similar volcanic effects. For example, the 1982 eruption of El Chichón in Mexico was widely expected to affect climate (*Science*, 10 September 1982, p. 1023), but no cooling appeared because it coincided with an El Niño. Take the effect of the El Niño out, however, as Mass and Portman and Angell did independently, and you see a global cooling of several tenths of a degree.

An understanding of this swamping of El Chichón's climate effect by El Niño can help in the search for the greenhouse warming.


U.S. Geological Survey

One that failed. *Mount St. Helens had the explosive power to loft ash into the stratosphere, but it lacked the sulfur to form a lasting, climate-altering aerosol.*

A Krakatau sunset. *Artist William Ascroft sketched this pastel on the bank of the Thames 3 months after the 1883 eruption of Krakatau in Indonesia. The eruption debris produced extraordinarily long and beautiful sunsets worldwide.* [*From plate 11 in* Krakatau, 1883—The Volcanic Eruption and its Effects, *T. Simkin and R. S. Fiske (Smithsonian Institution Press, Washington, DC, 1983). Originally from chromolithographs forming the frontispiece of the Royal Society of London's 1888 report on the eruption.*]

For example, the year 1983 was warmer than normal, but with the El Niño of the century under way and a greenhouse warming presumably accelerating, an all-time record would have seemed more likely. Those opposing the conclusion that the greenhouse is here now could cite the failure to set a record as further support for a wait-and-see approach. But knowing now that the volcanic veil from El Chichón tended to rein in any warming, scientists and policymakers might still argue for actions to control greenhouse gas emissions.

Climatologists seem to have demonstrated that eruptions will cool global temperatures, but they are still debating about how quickly this effect kicks in. "Several papers have suggested an immediate hemispheric cooling 1 to 3 months after an eruption," says Mass, "but I hope that we debunked that idea."

If the volcanic effect were as rapid as claimed by some, it would imply that the climate system is far more sensitive than computer models of climate suggest. One of Mass and Portman's arguments against such sensitivity is that in some suggestive cases the immediate cooling is merely a continuation of a pre-eruption cooling and is therefore unrelated to the eruption event. In other cases, it is an artifact of the data preparation, they say.

Try as Mass and Portman might, such physical and methodological reservations do not seem to have debunked immediate volcanic coolings just yet. "It's murky for the reasons Mass and Portman cite," says Raymond Bradley of the University of Massachusetts, who recently published his own study, "but, from my analysis, I'm pretty convinced there's an immediate effect." Only more large eruptions are likely to resolve this question.

Another remaining uncertainty is whether volcano-induced coolings have ever snowballed into prolonged episodes of cold. Some researchers have suggested, for instance, that concerted volcanic eruptions have cooled climate over decades, centuries, and even millions of years. The temperature records and the eruption records are best for the decade-by-decade changes of the past 100 years, but even then the records are not good enough to resolve the matter. Opinions still vary widely.

"Clearly, you can explain only a small amount of the variability during the past century with volcanoes," says Mass. "If the change is more than a few tenths of a degree or longer than 2 to 3 years, individual eruptions can't explain it." Mass contends that because only the few large eruptions have a demonstrable climatic effect, there simply have not been enough significant eruptions to explain, say, the global 0.2°C cooling between 1940 and 1960. Angell agrees. "It doesn't seem the big eruptions have had enough effect," he says.

On the other hand, "in the past 100 years," says climate modeler Alan Robock of the University of Maryland, "I think volcanoes were quite important. The '20s and '30s were a time of no large eruptions. The atmosphere was very clear, and it was warming." Robock, unlike Mass, sees a chance for closely spaced, moderate-size eruptions to have a significant cumulative effect on the atmoshpere.

Resolving the question of decadal volcanic effects will require a distinct improvement in the record of eruptions and their effect on the atmosphere. Geologists might have some idea of the size of many, though not all, eruptions, but an eruption's power over climate depends as much on its chemical composition as its size. Only tiny sulfuric acid droplets, derived from a volcano's gaseous sulfur, have lasting effects on the stratosphere such as cooling the lower atmosphere and creating gaudy sunsets. Ash falls out too quickly. There are good records for only the past few decades of the ash and acid that drift about in the stratosphere. Earlier than that, researchers are looking to such places as glaciers and polar ice sheets, where the stratosphere's acid fallout is preserved.

Sorting out matters of tenths of a degree may have academic as well as political implications, but the real drama in the volcano-climate arena is the potential for global disaster. The eruptions of the past century studied by Mass and Portman are geological midgets compared to earlier cataclysms. For instance, the large 1883 eruption of Krakatau produced only one-tenth of the ash of another Indonesian volcano, Tambora, which spewed 100 billion cubic meters 70 years earlier. This event was followed by "the year without a summer" in 1816 in New England and northern Europe, if not around the world. Snow and frosts in June and July brought hardship to both regions. Debate continues over whether even an eruption of that size could divert the jet stream and drop temperatures 5°C, as happened then.

But the geologic record gets more disastrous. As recently as 75,000 years ago, Toba in Indonesia spewed an estimated 1 trillion cubic meters of magma along with its accompanying gases. And even normally quiet, Hawaiian-style eruptions can rage into cataclysms. Fifteen million years ago the Columbia flood basalts surged over Oregon and Washington, some flows gushing 700 billion cubic meters of fluid lava in only a few days. Geologists stand in awe of these eruptions. Climatologists can only hope that they do not have a firsthand opportunity to record the atmosphere's reaction to such a megaeruption. ■ RICHARD A. KERR

ADDITIONAL READING

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