Chemistry of Volcanic Fallout Reveals Secrets of Past Eruptions

January 5 2007

A team of American and French scientists has developed a method to determine the influence of past volcanic eruptions on climate and the chemistry of the upper atmosphere, and significantly reduce uncertainty in models of future climate change.

In the January 5 issue of the journal *Science*, the researchers from the University of California, San Diego, the National Center for Scientific Research (CNRS) and the University of Grenoble in France report that the chemical fingerprint of fallout from past eruptions reveals how high the volcanic material reached, and what chemical reactions occurred while it was in the atmosphere. The work is particularly relevant because the effect of atmospheric particles, or aerosols, is a large uncertainty in models of climate, according to Mark Thiemens, Dean of UCSD's Division of Physical Sciences and professor of chemistry and biochemistry.

"In predictions about global warming, the greatest amount of error is associated with atmospheric aerosols," explained Thiemens, in whose laboratory the method, which is based on the measurement of isotopes—or forms of sulfur—was developed. "Now for the first time, we can account for all of the chemistry involving sulfates, which removes uncertainties in how these particles are made and transported. That's a big deal with climate change."

Determining the height of a past volcanic eruption provides important information about its impact on climate. If volcanic material only reaches the lower atmosphere, the effects are relatively local and short term because the material is washed out by rain. Eruptions that reach higher, up to the stratosphere, have a greater influence on climate.

“In the stratosphere, sulfur dioxide that was originally in the magma gets oxidized and forms droplets of sulfuric acid,” said Joël Savarino, a researcher at the CNRS and the University of Grenoble, who led the study. “This layer of acid can stay for years in the stratosphere because no liquid water is present in this part of the atmosphere. The layer thus acts as a blanket, reflecting the sunlight and therefore reducing the temperature at ground level, significantly and for many years.”

To distinguish eruptions that made it to the stratosphere from those that did not, the researchers examined the isotopes of sulfur in fallout preserved in the ice in Antarctica. The volcanic material is carried there by air currents. Thiemens, Savarino and two of their students traveled to Antarctica and recovered the samples by digging snow pits near the South Pole and Dome C, the new French/Italian inland station.

Sulfur that rises as high as the stratosphere, above the ozone layer, is exposed to short wavelength ultraviolet light. UV exposure creates a unique ratio of sulfur isotopes. Therefore the sulfur isotope signature in fallout reveals whether or not an eruption was stratospheric.

To develop the method, the team, which also included Mélanie Baroni, the first author on the paper who is a postdoctoral fellow working with Savarino, and Robert Delmas, a research director at the CNRS, focused on two volcanic eruptions. Both eruptions, the 1963 eruption of Mount Agung in Bali and the 1991 eruption of Mount Pinatubo in the Philippines, were stratospheric according to the isotope measurements.

“Young volcanoes have the advantage of having been documented by modern instruments, such as satellites or aircraft,” said Savarino, who began his investigations into sulfur isotope measurements when he was a postdoctoral fellow working with Thiemens. “We could therefore compare our measurements on volcanic fallout stored in snow with atmospheric observations.”

Not only did their isotope measurements match the atmospheric observations, they were also able to distinguish the Pinatubo eruption from the eruption of Cerro Hudson that occurred the same year. Cerro Hudson did not send material as high as the stratosphere and the fallout had a different sulfur isotope fingerprint than the fallout from Pinatubo.

Volcanic material from more ancient eruptions is preserved in Antarctica, but the older, deeper seasonal layers of ice are extremely thin as a result of the pressure from the overlying ice. Therefore, it is not currently feasible to extract enough fallout from the ice to apply the isotope method to all past volcanoes. However, data from eruptions in the recent past reveal what chemical reactions of sulfates occur in the upper atmosphere.

Some scientists have proposed that if global warming becomes severe, sulfates could be injected into the stratosphere in order to block some of the incoming solar radiation and reduce the temperature. Thiemens explained that understanding the chemical reactions of sulfates in the stratosphere is critical to determining if this approach would be effective.

“Sulfates can cause warming or cooling depending on how they are made,” he said. “They are usually white particles, which tend to reflect sunlight, but if they are made on dark particles like soot, they can absorb heat and worsen warming.”

Source: University of California, San Diego