Haze Clouds the Greenhouse

Sulfur pollution has slowed the global warming

By RICHARD MONASTERSKY

High above our heads, two kinds of pollution are waging a tug-of-war over Earth's climate.

Greenhouse gases, with their much-publicized warming powers, hold the decided advantage in this environmental struggle. But another form of pollution is showing unanticipated strength as it pulls against the greenhouse forces, reducing the rate of warming.

Atmospheric experts have long suspected that sulfur haze – the same kind that obscures skylines in much of the industrialized world – could exert a cooling effect by reflecting sunlight. Yet they are only now recognizing sulfur's potential power.

The Intergovernmental Panel on Climate Change (IPCC) recently recognized the importance of the sulfur issue in its 1992 review, released in mid-January. While the international panel stood by its 1990 conclusion that greenhouse gas emissions are likely to raise Earth's temperature significantly, it scaled back the estimated warming rate, largely because of the influence of sulfur pollution. The report concludes that "the cooling effect of sulfur emissions may have offset a significant part of the greenhouse warming in the northern hemisphere during the past several decades."

One of the U.S. participants in the IPCC assessment, climate modeler Michael C. MacCracken of the Lawrence Livermore (Calif.) National Laboratory, says the panel included this point because newer studies have found the sulfur emissions more significant than previously thought.

"It's a topic whose time has come," says Robert J. Charlson, an atmospheric scientist at the University of Washington in Seattle who has long studied the effects of sulfur pollution.

Formed during the combustion of fossil fuels, sulfur pollution pours from the same smokestacks and tailpipes that belch out 6 billion tons of carbon dioxide each year. The sulfur dioxide gas wafts into the atmosphere, where it eventually turns into tiny sulfuric acid "aerosols," which can be either droplets or particles.

Sulfur aerosols tug on the climate in two ways – one direct, the other more subtle. Aerosols exert their most obvious effect by reflecting incoming solar radiation back toward space. They wield indirect climatic power by serving as nuclei around which water vapor can condense to form sunlight-reflecting cloud particles. In both cases, aerosol pollution acts as a giant shade, reducing the amount of light reaching Earth's surface.

Over the last few years, Charlson and other atmospheric experts have gradually realized that the aerosol effect warranted consideration. They wondered: Could the sulfur shade actually block enough of the sun's energy to slow the greenhouse warming? To answer that question, researchers would need to estimate the power of aerosols and compare it with that of greenhouse gases.

Climate modelers have a reasonably good handle on the greenhouse part of the equation. Since the beginning of the Industrial Revolution, emissions of carbon dioxide, methane and other gases have added about 2 to 2.5 watts of energy for each square meter of Earth's surface – the equivalent of hanging two Christmas-tree lights over every square meter of the planet.

The aerosol factor isn't nearly so clear. Charlson and six colleagues recently joined together to present a consensus statement – at least for the United States – on aerosols. In the Jan. 24 SCIENCE, they estimate that the direct influence of sulfur aerosols, averaged over the globe, amounts to roughly 1 W/m^2. The real value, they say, could range from 0.5 to 2.0 W/m^2.

The global average may have little meaning, though, because sulfur aerosols assert themselves most forcefully in the northern hemisphere, which contributes 90 percent of the world's sulfur pollution. Aerosols remain in the atmosphere only a few days, so they haven't time to spread around the world, unlike the long-lasting greenhouse gases. Charlson and his colleagues estimate that the sulfur effect over the northern hemisphere may be double the global average.

For all the uncertainty about sulfur's direct effect, climate researchers face an even more daunting task in gauging its indirect influence. Atmospheric scientists do not know to what extent aerosols increase the number of particles within a cloud, one of the critical determinants of how much sunlight clouds reflect. Charlson's group offers only a very rough estimate, proposing that the indirect

A capitol offense: Two photographs taken from the same location show haze's dramatic effect on the skyline of Washington, D.C. Left photo was taken at 3 p.m. on May 28, 1989; right photo was taken at 9 a.m. on Dec. 7, 1988.

cooling factor may measure about 1 W/m^2.

Burning of forests, grasslands and agricultural fields releases other kinds of aerosols that may also cool the climate, but scientists know even less about these nonsulfur aerosols.

Charlson and his coauthors say a concerted effort is required to improve understanding of aerosols. They propose a comprehensive approach involving satellite-borne sensors, a network of ground-based instruments and intensive measurements by aircraft.

Despite the glaring uncertainties, Charlson says aerosols clearly exert a significant cooling effect over some parts of the globe. Their combined direct and indirect influences may be just about as strong as the greenhouse gases, he and his colleagues believe.

Climate modelers might view the sulfur factor as both a blessing and a curse. On the positive side, the aerosol effect could explain why the northern hemisphere has warmed only half as fast as computer simulations predicted it would in response to rising levels of greenhouse gases. Without this possible explanation, modelers must wonder whether they have made a fundamental mistake in the way they have represented the greenhouse aspect of the problem.

Seen from a different angle, the sulfur issue injects one more major uncertainty into the business of capturing climate on computer. And because aerosol concentrations vary so much from place to place, they could strongly influence how individual regions respond to greenhouse gas pollution.

"We're concerned about regional-scale changes in meteorological processes, like the frequency of storms, the amount and timing of rain and whether we have rain or snow," says Charlson. "Those are the things that will actually matter in terms of their impact on humans. It's very clear that we're a long way from being able to [predict] that. And I think the aerosol problem makes that an even more challenging task."

One might be tempted to view sulfur pollution as a shield against the warming effect of greenhouse gases, but researchers who have studied aerosols reject that notion, for a number of reasons.

Sulfur pollution causes acid rain and creates view-robbing haze, not only in cities but also in rural areas such as the Grand Canyon. The United States and many other nations are currently attempting to reduce sulfur emissions, not encourage them.

What's more, sulfur aerosols do not provide true protection against greenhouse gases, climate experts say. The pollutant aerosols don't exist in high concentrations over most of the southern hemisphere and many regions of the northern hemisphere. This patchy distribution could alter precipitation patterns or other meteorological factors, says Charlson. So even if sulfur pollution slows a temperature rise in one region, it might not protect that region from droughts, floods, sea-level rise or other consequences of climate change.

Some studies suggest that aerosol pollution can make clouds more stingy with water, so they release less rain (SN: 8/12/89, p.106), another potentially harmful effect.

Moreover, aerosols do not provide cooling power at night, whereas greenhouse gases trap heat 24 hours a day. Perhaps because of this difference, a significant amount of nighttime warming has occurred over the last 40 years in the United States, China and the former Soviet Union (SN: 1/4/92, p.4).

Researchers remain uncertain whether such a nighttime warming trend benefits humans. "Your instant reaction is that it ought to increase the growth [of crops], but there are some other things involved that are kind of hidden," says Frank Quinlan, a climatologist at the University of North Carolina in Asheville. Some studies suggest that nighttime warming has occurred in regions where cloudiness has increased, perhaps because of aerosol pollution. So while warmer temperatures may help plants grow, increasing cloud cover may block some sunlight, an effect that would tend to slow plant growth, Quinlan suggests.

In the long run, sulfur pollution cannot keep pace with greenhouse gases, because the latter persist in the atmosphere for hundreds of years, says James Hansen, a climate modeler at NASA's Goddard Institute for Space Studies in New York City. These long-lived gases accumulate in the atmosphere much faster than the short-lived aerosols do.

Hansen warns that sulfur aerosols may foster a false sense of security by masking the full extent of the greenhouse problem at precisely the time when intervention is most feasible. "We may have a larger warming in store than the present trend would suggest," he says.

In the tug-of-war between aerosols and greenhouse gases, it seems that humans may be the real losers. □

Trying to see the forest through the haze

The television meteorologist hands out the bad news: "Tomorrow will bring another of those miserable 3-H days – hazy, hot and humid for the metropolitan area."

East Coast residents have grown all too familiar with that particular summer forecast, perhaps not realizing that conditions were different earlier in the century. While summertime heat and humidity have blanketed this region since long before cities arose, the ubiquitous veil of haze developed only when people began burning significant amounts of fossil fuels, notes John Trijonis, an air pollution expert with Santa Fe Research Corp. in Bloomington, Minn.

Haze consists of aerosols – tiny droplets or particles that can reduce visibility by scattering or absorbing sunlight.

National Park Service

Atmospheric studies have shown that pollution creates roughly 80 to 90 percent of atmospheric aerosols; the rest comes from natural sources such as dust, pollen and gases released by vegetation. Sulfur pollution, which can exert a cooling effect on the climate, accounts for about three-quarters of the pollutant aerosols, Trijonis says.

Europe, China and the eastern United States suffer the worst haze problems, reflecting a heavy reliance on sulfurous coal in these regions. "If you fly from, say, New York to New Orleans or from Chicago to Miami, you'll see [haze] all the way. It's just so widespread, with no obvious source, you sort of assume it's natural," Trijonis says.

Haze can have dramatic visual effects. On a pristine day, the limit of visibility in the eastern United States is in the range of 150 kilometers; but haze cuts the average range of sight to only 25 kilometers, Trijonis found in a study for the National Acid Precipitation Assessment Program (SN: 3/3/90, p.143). Although western states also have haze, they burn less coal and therefore face a less severe problem.

Before the middle part of this century, summer was the least hazy season because coal use dropped to a minimum at this time of the year. The proliferation of air conditioners increased summertime electricity demands, causing power companies to burn more coal during the warmest months.

– R. Monastersky