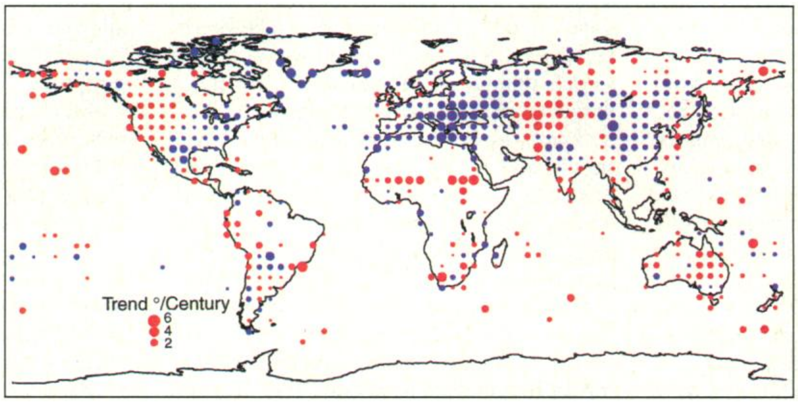
Study Unveils Climate Cooling Caused by Pollutant Haze

Human beings may be turning up Earth's thermostat as they pump carbon dioxide and other greenhouse gases into the atmosphere, but they are drawing the shades against the sun's warmth at the same time. In recent decades, a pall of microscopic particles from smokestack emissions has thickened over large parts of the planet, reflecting sunlight back into space. Theory says that this aerosol should be cooling the surface, perhaps enough to mask much of the greenhouse effect and slow down any ongoing global warming (*Science*, 7 February 1992, p. 683). But climate researchers have had a hard time pinning down a clear signal of aerosol cooling.

Now a detailed analysis of temperature and emission records for large areas of the Northern Hemisphere has yielded what researchers are greeting as persuasive evidence of aerosol cooling. In a paper to be published next month in the proceedings of a workshop held in Dahlem, Germany, climatologist Thomas Karl of the National Climatic Data Center (NCDC) in Asheville, North Carolina, and his colleagues show that the cooling effect has been strongest where aerosol pollution is heaviest—and it changes over time, depending on emissions. "The evidence is pretty substantial that we are seeing the aerosol effect," says climate modeler Jeffrey Kiehl of the National Center for Atmospheric Research. And that effect looks strong enough to have taken a large bite out of the greenhouse warming to date. "To understand regional or even global climate change," says Kiehl, "we have to factor in the aerosols."



Cool and hazy. Northern summer temperatures dropped in regions that have the most pollution to block sunlight: eastern North America, central Europe, and eastern Asia. Blue indicates decreasing temperatures; red, increasing temperatures.

Gauging the effect of aerosols has been difficult because theory provides so little help in estimating how big it should be. Theorists trying to calculate the amount of sunlight reflected by the microscopic particles, made up mostly of sulfate that forms from the sulfur oxides emitted by power plants and industry, have disagreed by as much as a factor of 4. And estimates of an additional, indirect cooling effect that could result when aerosols thicken clouds by forming additional cloud droplets have been even more uncertain.

Still, just eyeballing a map that shows where the globe has warmed and cooled in recent decades is enough to suggest that aerosols are at work, as Karl and his colleagues Richard Knight of NCDC and George Kukla and Joyce Gavin of Columbia University's Lamont-Doherty Earth Observatory found when they mapped global temperature trends. They saw warming over the globe as a whole since midcentury, but summer temperatures over eastern North America, Europe, and eastern Asia cooled noticeably (see figure). Those are just the areas where most of the aerosol pollution enters the atmosphere. And summers, when there's the most sunlight to be reflected, are just when the strongest aerosol effect should show up.

To test whether the summer cooling was driven by increasing aerosols or was just a random jiggle in the climate system, Karl and his colleagues did some statistical analyses. They divided the Northern Hemisphere between 20°N and 60°N into nine latitudinal bands and, for each band, correlated the change in sulfur emissions between 1966 and 1980 with the change in temperature over the same period. In every one of the nine bands, sulfur emission increased and summer temperature decreased—a consistency that "strongly supports" a link between aerosols and cooling, the authors write.

As a separate test, Karl and his colleagues focused on the United States without Alaska and Hawaii, an area for which detailed temperature and emissions records are available. The temperature data allowed the researchers to look specifically at summer daily maximum temperatures, where any aerosol cooling should be strongest, and at minimum temperatures, which should show little effect, because they depend more on nighttime heat loss than daytime heating. The emissions records, meanwhile, allowed them to search for a change in the summer temperature trends before and after 1970, when the U.S. Clean Air Act went into effect and began cutting sulfur emissions.

As theory predicted, maximum temperatures in the lower 48 states decreased from 1950 to 1970, when sulfur emissions were increasing, then went up again when the emissions controls cut in. Minimum temperatures showed no tendency to vary with sulfur emissions—also as expected. "The [aerosol] signal comes in pretty strongly and is much clearer" than in earlier, less detailed studies, says Karl. "You get signals that stand out at the 5% significance level." Benjamin Santer of Lawrence Livermore National Laboratory agrees that "you can make a reasonably strong case, at least regionally," that aerosols are cooling the climate. "Tom's work shows that if you do the statistics, there is a significant relation."

Not only is there a statistically significant relation, but "the reduction of temperature is large enough to have an impact on global temperatures," says Karl. From the magnitude of the U.S. cooling and warming before and after the Clean Air Act, he roughly estimates that the 21 million tons of sulfur now released every year over the United States are keeping the mean temperature about 1°C cooler than it would be otherwise. Over the entire Northern Hemisphere, he estimates a cooling of about 0.5°C.

Because the global warming observed over the past century is also just half a degree, aerosol cooling is clearly something for climate modelers to reckon with. It might, for example, help explain the disparity between the observed warming and the degree or so of greenhouse warming that computer climate models generally predict, says Santer. He adds that the varying regional impact of aerosols may have confounded attempts to find the distinctive geographic pattern of warming that would finally implicate greenhouse gases. The key to recognizing greenhouse warming, it seems, may be global cooling.

–Richard A. Kerr

Additional Reading

T. R. Karl *et al.*, "Evidence for radiative effects of anthropogenic sulfate aerosols in the observed climate record," in *Aerosol Forcing of Climate*, R. J. Charlson and J. Heintzenberg, Eds., pp. 363–382 (John Wiley & Sons, Ltd., Chichester, U.K., in press).