



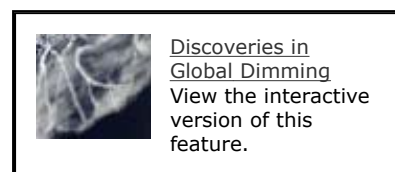
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Discoveries in Global Dimming ||

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In the early 21st century, it's become clear that air pollution can significantly reduce the amount of sunlight reaching Earth, lower temperatures, and mask the warming effects of greenhouse gases. Climate researcher James Hansen estimates that "global dimming" is cooling our planet by more than a degree Celsius (1.8°F) and fears that as we cut back on pollution, global warming may escalate to a point of no return. Regrettably, in terms of possibly taking corrective action, our current understanding of global dimming has been a long time in the coming, considering the first hints of the phenomenon date back to 18th-century observations of volcanic eruptions. Below, follow a series of historic events and scientific milestones that built the case for global dimming.—*Susan K. Lewis*



Thanks to Spencer Weart of the American Institute of Physics, whose book *The Discovery of Global Warming* made this feature possible. A hypertext version of the book can be found at www.aip.org/history/climate/



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Laki Eruption Cools Europe 1783

For millennia humans no doubt have noticed that smoke and ash from volcanic eruptions can block sunlight for many days. But Benjamin Franklin went a step further in 1783, proposing that a massive volcanic eruption of the Laki fissure in Iceland caused months of unusually cold weather in Europe. By the early 1900s, scientists had begun trying to quantify how volcanic eruptions affect climate, but measurements and climate models were too crude to conclusively link the two. It wasn't until the late 20th century that scientists understood precisely how Laki's eruption and the subsequent strange blue haze that wafted over Europe cooled temperatures, and how this

related to the "human volcano" of air pollution.

Left: Part of the 16-mile-long Laki fissure today. When this volcanic ridge opened in 1783, altered weather patterns led to the greatest famine in Iceland's history.



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WWII Spurs Aerosol Science 1940s

Before scientists could even be in a position to suspect such a subtle phenomenon as global dimming, they had to gain a better understanding of aerosols, particles suspended in a gas. World War II provided them with that opportunity, as researchers investigated various types of smoke, poison gas, and nuclear fallout. Studies done for the Manhattan Project, in fact, led to the first handbook of aerosol science. Nevertheless, for decades after the war, few aerosol experts tackled issues directly related to climate change.

Left: How far would radioactive particles from nuclear explosions travel? The need to understand such issues sparked aerosol science, but wartime research was not always openly published.




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Cloud "Seeding" Attempted 1950s

Scientists knew that clouds form only when there are tiny particles in the air such as sea salt or pollen around which water droplets can condense. In the 1950s, various government and commercial groups began exploring whether it would be possible to "seed" clouds with silver iodide smoke and other substances in order to make rain and control local weather. The widespread cloud seeding efforts ultimately had very limited success. But they prompted suspicion, borne out decades later, that human pollution was inadvertently creating clouds that intercepted sunlight and impacted the climate of a broad region.

Left: Cloud-seeding studies took place in skies around the world. Here, a 1957 effort near Sydney, Australia



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
Pollution's Far Reach

1960s

By midcentury, rising levels of smog in cities had triggered public outcry and captured the attention of aerosol scientists. Most of the focus initially was on large particles that fell from the sky in a matter of days. In the 1960s, however, experts began studying how microscopic particles could linger longer and travel farther. Experts set up networks of monitoring stations to regularly measure atmospheric turbidity, commonly known as haze. In 1967, Robert McCormick and John Ludwig of the National Center for Air Pollution Control reported a rise in turbidity over regions spanning as much as 600 miles. Even remote areas of the Arctic appeared affected. It seemed likely that both industrial pollution and haze caused by slash-and-burn agriculture in the developing world were having a global reach.

Left: The infamous smog of Los Angeles, despite countless clean air reforms since the 1940s, still plagues the city today.



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Ice Cores Reveal Past Trends

Late 1970s-early 1980s

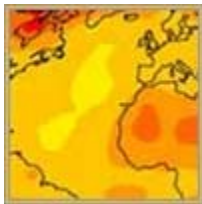
Looking at ice cores from Greenland spanning hundreds of centuries, scientists repeatedly saw telltale signs that giant volcanic eruptions of dust and sulfuric acid were followed by cooler temperatures in subsequent years. On a different but related front, other experts realized that sulfuric acid and other small particle sulfates could stay in the stratosphere for years, persisting much longer than larger particles. Sulfate aerosols, whether generated by volcanoes or by humans burning coal, oil, and other fossil fuels, now seemed likely culprits in climate cooling.

Left: Layers of ancient ice drilled from the immense Greenland ice sheet offered clues that volcanic eruptions had triggered climate cooling.

Early Computer Climate Models

Mid-to-late 1970s

Early computer models of the global climate attempted to factor in aerosols. It was a daunting task: A wide



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spectrum of aerosols exists in the atmosphere—small sulfate particles, salt crystals from the oceans, soot, and many others. How these particles, at various heights, cause absorption or reflection of the sun's radiation was poorly understood. Yet different groups of modelers came to the same tentative conclusion. Human-made aerosols, they found, were contributing to cloud formation, increasing the planet's reflectivity, and causing a modest cooling. Some scientists even suggested that air pollution, if unrestrained, might trigger a new ice age. Yet great uncertainty remained over how the complex mix of pollution affected the climate.

Left: More recent and sophisticated computer models confirm what earlier models glimpsed. Today, using a version of NASA's global climate computer model, even high school students can run climate change scenarios.



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Dinosaur Extinction Theory Early 1980s

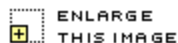
In 1980, Walter and Luis Alvarez proposed that a giant asteroid striking Earth 65 million years ago had sent enough debris into the atmosphere to cool the planet and kill off the dinosaurs. The dinosaur extinction theory aroused public awareness of how rapidly Earth's climate might change. It also encouraged aerosol and climate scientists to look more closely at issues related to global dimming. A few years later, in 1983, a different theory had a similar effect, when aerosol scientists warned that nuclear war could lead to an apocalyptic "nuclear winter."

Left: Whether dinosaurs died out because a giant asteroid hit Earth or because volcanic eruptions clouded the skies (another leading theory), the basic mechanism of global cooling was the same.



Shipping Lane Clouds 1987

Scientists had long theorized that air pollution might be "seeding" the formation of clouds. But decades of cloud-seeding experiments had failed to provide proof, and evidence for pollution-related clouds was tenuous. More conclusive evidence came in 1987, when satellite photos revealed persistent clouds over areas of the oceans used as shipping lanes. Smokestack exhaust from ships, dense



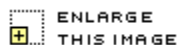
with sulfate aerosols, was creating clouds that likely reflected sunlight and decreased the solar energy warming the ocean surface.

Left: A 2003 satellite image of "ship tracks" off the Pacific Northwest coast. The tracks appear as bright white squiggles within a thinner veil of cloud cover. Shipping lane clouds form only in extremely humid air.

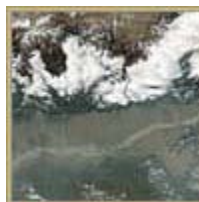


Pinatubo Confirms Climate Models 1991

When Mount Pinatubo in the Philippines erupted, climate scientists seized the opportunity to test their models. The eruption released some 20 million tons of sulfur dioxide into the atmosphere, giving rise to a lingering haze of sulfate aerosols. NASA researchers led by James Hansen calculated that Pinatubo's eruption would lower average global temperatures over the next few years by roughly half a degree Celsius (0.9°F), with the greatest changes in the higher northern latitudes. The prediction proved remarkably on target. By the mid-1990s, most scientists agreed that human-made aerosols were acting like an ongoing volcanic eruption, and that air pollution had likely been masking the impact of global warming for decades.

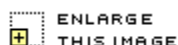


Left: For months after Pinatubo's eruption, a haze of sulfate aerosols hovered in the stratosphere, just as had happened in 1783 after Laki erupted in Iceland.



Indian Ocean Study Late 1990s

In a \$25 million multinational study spanning four years, climate scientists led by Veerabhadran Ramanathan documented how pollution was severely dimming areas of the Indian Ocean. The study, called Project INDOEX, found that over northern regions of the ocean, where pollution streams in from India, a pollutant layer nearly two miles thick cut down the sunlight reaching the ocean by more than 10 percent—a far bigger effect than most scientists had thought possible. Ramanathan's own models had led him to expect a dimming of only one half to one percent. Project INDOEX showed in detail how the toxic mix of soot, sulfates, and other pollutants both directly blocked sunlight and, even more critically, helped




DIMMING THE SUN

The Contrail Effect
Are vapor trails from aircraft influencing

spawn clouds that reflected the sun's energy back to space.

Left: This 2001 satellite image captures the toxic aerosol haze blanketing northern India and Bangladesh, south of the Himalayan Mountains.



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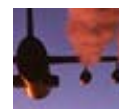
Dimming Recognized Worldwide Mid-1980s to present

In the mid-1980s, when meteorologist Gerry Stanhill reported that a dramatic 22 percent reduction of sunlight had occurred in Israel between the 1950s and the 1980s, the news hardly made a splash in the scientific community or popular press. But Stanhill was not alone in measuring such a drop. When he combed the scientific literature, he found that other scientists had measured declines of 9 percent in Antarctica, 10 percent in areas of the U.S., 16 percent in parts of Great Britain, and almost 30 percent in one region of Russia. Alarmed by the trend, Stanhill coined the term "global dimming." By the turn of the 21st century, with mounting evidence of just how human pollution had caused it, global dimming finally gained the attention it warranted.

Left: NASA's Aqua satellite, launched in 2002, is filling in details in the big picture of global dimming. Data from Aqua indicates that aerosol pollution is cooling the climate by more than a degree Celsius (1.8°F).

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the climate?



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