

## Black Carbon Aerosol Pollution Cools, Heats, Confuses

New research based on NASA satellite data and a multinational field experiment shows that black carbon aerosol pollution produced by humans can impact global climate as well as seasonal cycles of rainfall.

Because aerosols that contain black carbon both absorb and reflect incoming sunlight, these particles can exert a regional cooling influence on Earth's surface that is about 3 times greater than the warming effect of greenhouse gases.

But even as these aerosols reduce by as much as 10 percent the amount of sunlight reaching the surface, they increase the solar energy absorbed in the atmosphere by 50 percent -- thus making it possible to both cool the surface and warm the atmosphere.

Scientists are concerned that this heating may perturb atmospheric circulation and rainfall patterns.

"When we combined the satellite measurements with surface measurements, we found that the reduction of sunlight reaching the surface was three times larger than the amount of sunlight reflected to space," says V. Ramanathan, director of the Center for Clouds, Chemistry, and Climate at Scripps Institution of Oceanography at the University of California, San Diego. "Averaged over the entire northern Indian Ocean, the man-made pollutants reflected more solar radiation back to space (than pristine skies), but they absorbed up to twice as much radiation in the atmosphere."

Together with K. Rajeev of India's Vikram Sarabhai Space Center, the authors reported their findings in the August 16 *Journal of Geophysical Research*.

Data for their investigation were collected during the Indian Ocean Experiment (INDOEX) -- an international multi-agency measurement campaign conducted from January through March in the years 1997, 1998 and 1999.

INDOEX used instruments on land and on aircraft together with measurements made by NASA's Clouds and Earth's Radiant Energy System (CERES) sensor as it flew overhead aboard the Tropical Rainfall Measuring Mission (TRMM) satellite.

The experiment's objective was to help scientists understand to what extent human-produced aerosols may offset global warming. Earlier global warming studies suggest aerosols make our world "brighter" by reflecting more sunlight back to space, thereby helping to counteract the

greenhouse effect.

The Indian subcontinent offered the architects of the INDOEX campaign an ideal setting for their field experiment. The region was chosen for its unique combination of meteorology, landscape (relatively flat plains framed by the towering Himalayan Mountains to the north and open ocean to the south), and the large Southern Asian population (roughly 1.5 billion) with a growing economy.

"Together, these features maximize the effects of aerosol pollution," Ramanathan explains. As a result of human industry -- automobiles, factories and burning vegetation -- particles build up in the atmosphere where they are blown southward over most of the tropical Indian Ocean. The Indo-Asian haze covered an area larger than that of the United States.

Although the INDOEX team found atmospheric particles of natural origin -- such as trace amounts of sea salts and desert dust -- they also found that 75 percent of the aerosol over the region resulted from human activities -- including sulfates, nitrates, black carbon and fly ash.

Most natural aerosols scatter and reflect sunlight back to space, thereby making our planet brighter. However, human-produced black carbon aerosol absorbs more light than it reflects, thereby making our planet darker.

"Ultimately, we want to determine if our planet as a whole is getting brighter or darker," Ramanathan states. "We could not answer that question until we could measure the sunlight reflected at the top of the atmosphere with an absolute accuracy of 1 percent. The CERES sensors provide that accuracy for the first time ever from a space-based sensor."

CERES was first launched in 1997 aboard TRMM, which flies in a near-equatorial orbit. Two more CERES sensors were launched in December 1999 aboard NASA's Terra satellite, which flies in a near-polar orbit. Terra's polar orbit allows CERES to measure the Earth's incoming and outgoing radiant energy on a global scale every day.

Moreover, the Moderate-resolution Imaging Spectroradiometer (MODIS) aboard Terra makes precise global measurements of aerosols that greatly enhance scientists' ability to study their effects.

"A large reduction of sunlight at the surface has implications for the hydrological cycle because of the close tie between heat and evaporation," Ramanathan says. "It could change the heating structure of the atmosphere and perturb the climate system in ways we don't understand now. We don't know, for example, how this might affect the monsoon season."

While Ramanathan admits that scientists don't know the net effect of bright and dark aerosols on global climate, through INDOEX and CERES they have shown that aerosols have a net cooling effect on the surface

and they now know the magnitude of that cooling over a large region.

But, he says, the INDOEX campaign does not solve the greater mystery. The next step is to use the CERES and MODIS sensors aboard NASA's Terra satellite to extend this study to the global scale.

The study was funded by the National Science Foundation.

Images and animations are available at [this URL](#).

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