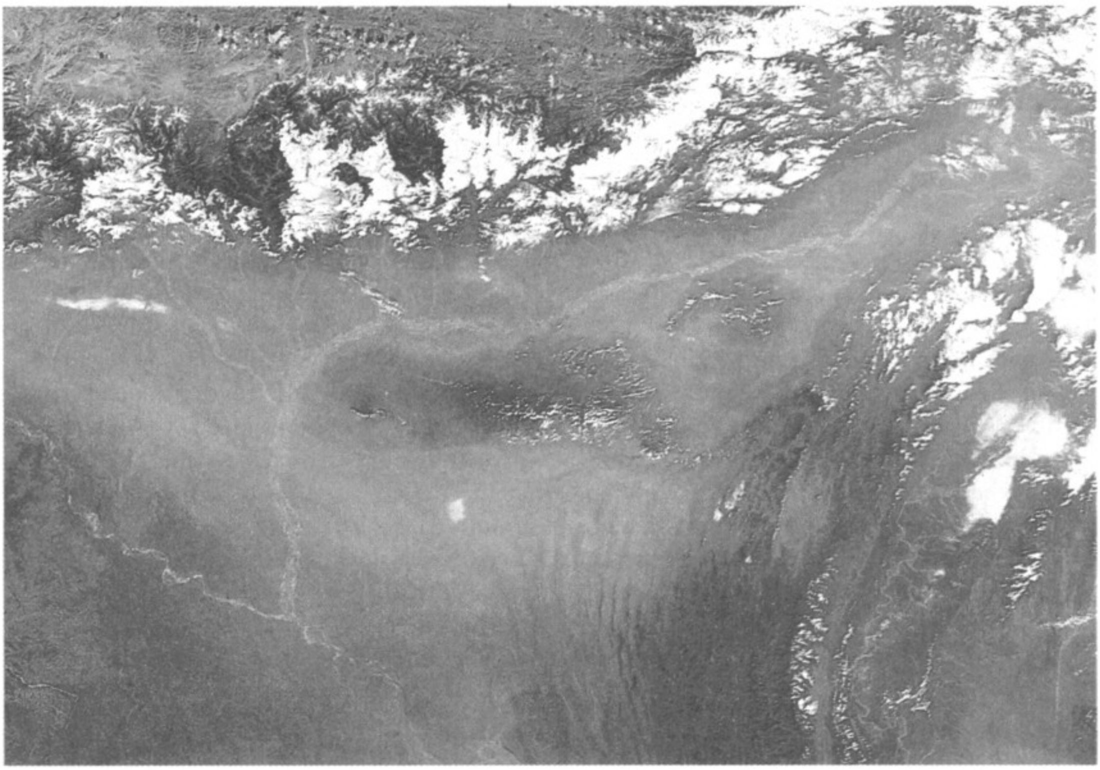
Aerosols

The Earth's sun shield

Aerosols are produced by natural processes and human activities. They differ in nature and act in complex ways on climate, says **N. Gopal Raj**



Satellite image of haze over India and Bangladesh. PHOTO: NASA

The Intergovernmental Panel on Climate Change (IPCC) was blunt when it issued its Fourth Assessment Report in 2007. "Warming of the climate system is unequivocal," it warned and said growing concentrations of greenhouse gases produced by human actions were to blame. The IPCC report also indicates that the warming of the planet would be much greater than it is currently if it were not for the presence of tiny particles known as aerosols that remain suspended in the atmosphere.

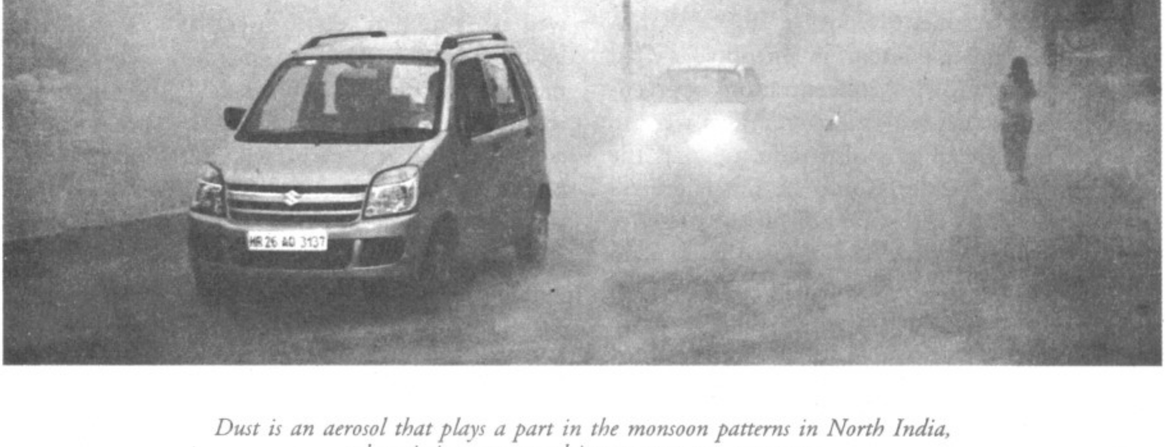
However, these particles affect the climate in ways that are complex and still imperfectly understood. So much so that the IPCC report noted that such effects remained the dominant uncertainty in coming up with climate change forecasts. Aerosols can be produced naturally, for example, from dust and sea-salt whipped up by winds, as well as by human activity, such as soot produced by the incomplete burning of fossil fuels and biomass. By acting like a sun-shield, these particles reduce the light that reaches the ground, thus cooling the Earth's surface. Particles like sulphates, generated by natural processes as well as from the burning of fossil fuels, can, in addition, reflect sunlight back into space, thereby cutting down atmospheric heating as well. On the other hand, soot, which strongly absorbs light, has the reverse effect and increases the heating up of the atmosphere. Such heating can inhibit cloud formation. On the other hand, the presence of more water-absorbing particles in the atmosphere, such as sea-salt and sulphates, can lead to the formation of more cloud droplets, which are smaller in size. The increased cloudiness reflects more sunlight away and less of it reaches the ground. Besides, the tinier cloud droplets can increase the lifetime of clouds. As a result, the dimming can persist for longer periods, enhancing the cooling generated by such particles.

Different types of aerosols can affect the climate in completely different ways. Moreover, such properties can change considerably when aerosols are mixed. Unlike greenhouse gases that are long-lived (carbon dioxide, for instance, has a lifetime of 100 years or more), aerosols remain in the atmosphere for just one to three weeks. Thus, while greenhouses gases are quite uniformly mixed globally, there are tremendous regional and seasonal variations in aerosol concentrations. There are substantial year-to-year variations too, especially in the levels of naturally occurring aerosols.

Global concentrations of carbon dioxide and other greenhouse gases can be accurately estimated from a few measurements, pointed out J. Srinivasan of the Centre for Atmospheric and Oceanic Sciences at the Indian Institute of Science in Bangalore, who was one of the lead authors involved in the preparation of the IPCC Fourth Assessment Report. Carrying out a similar exercise for aerosols was highly problematic because the levels of different types of these particles varied greatly spatially and over time. Thus, computing the global climate impact of aerosols was extremely imprecise and should not be equated with those of greenhouse gases, which could be estimated with reasonable accuracy, he argued.

In recent years, there has been growing interest in the impact of soot. Unlike carbon dioxide that heated up both the atmosphere and the earth's surface, soot had the opposing effects of adding energy to the atmosphere and reducing it at the earth's surface, noted a review paper published recently by V. Ramanathan of the Scripps Institution of Oceanography in California and G. Carmichael of the University of Iowa. They argued that the warming effect of soot in the atmosphere was three to four times greater than had been previously estimated. Soot could be having an impact of as much as 60 per cent of the current global warming effect of carbon dioxide, they suggested. "Until about the 1950s, North America and Western Europe were the major sources of soot emissions, but now developing regions in the tropics and East Asia are the major source regions," Dr. Ramanathan and Dr. Carmichael said in their *Nature Geoscience* paper.

In India, soot emissions had jumped by around 61 per cent between 1991 and 2001, according to estimates prepared by S.K. Sahu of the Indian Institute of Tropical Meteorology in Pune and his colleagues that were published in the journal *Geophysical Research Letters* this year. Those



Dust is an aerosol that plays a part in the monsoon patterns in North India, where it is encountered in some seasons. PHOTO: PTI estimates suggest that more than half the soot could be coming from coal used by thermal power plants as well as in the manufacture of steel and cement. Vehicular emissions could be producing about a third of the total soot generated, with the balance coming from the burning of firewood, dung and crop residues.

Thick bands of pollution

Dr. Ramanathan and Dr. Carmichael draw attention to the thick bands of pollution, which have been termed 'atmospheric brown clouds'. The soot particles give the dusky hue to these clouds, which also contain sulphates from the burning of coal, nitrates from vehicle exhaust and fly ash mixed with natural aerosols such as sea salt and dust. The hotspots for such brown clouds included the Indo-Gangetic plains, eastern China, most of Southeast Asia as well as parts of Africa and South America. More than three billion people live in these hot spots, they point out. In a paper published in *Nature* in 2007, Dr. Ramanathan and others said that heating produced by soot in the clouds of pollution hanging over south and east Asia could be contributing to the retreat of the Himalayan glaciers. The atmospheric brown clouds contributed as much as the recent increase in human-produced greenhouse gases to the heating of the lower atmosphere in the region, they added. Research carried out by S.N. Tripathi and his team at IIT Kanpur gives an idea of the flow of aerosols in the Indo-Gangetic basin, a polluted region.

Vehicular emissions could be producing about a third of the total soot generated.

Scientists use 'aerosol optical depth' (AOD) as a measure of the amount of aerosols present in the atmosphere. Sulphates, nitrates from the fertilisers used in agriculture and soot accounted for nearly 80 per cent of the AOD over Kanpur in winter, according to Dr. Tripathi. In summer, the level of these pollutants halved. Although soot contributed to just 12 per cent of the AOD in Kanpur in winter and half as much in summer, the sunlight absorbed by these particles could nevertheless be producing considerable heating of the atmosphere, he remarked. Some of the soot appeared to be coming from beyond India's borders, he added. But in the pre-monsoon months, from April to June when the AOD was at its maximum, dust was the predominant aerosol over Kanpur, said Dr. Tripathi. Some of the dust came from the deserts of Rajasthan and some of it from the Middle East, sometimes from as far away as Oman. When dust got mixed with soot, the latter appeared to form a coating over the dust particles. The resultant combination absorbed more light than soot alone and therefore could produce greater heating of the atmosphere, he added. Atmospheric heating and dimming by soot and non-soot aerosols could "perturb the monsoon significantly," said Dr. Ramanathan and Dr. Carmichael in their paper.

Declining rainfall over the last 50 years in many regions of the tropics, particularly over Africa, South Asia and southern China, could not be explained solely by global warming, they noted. The dimming of sunlight produced by aerosols reduced evaporation from the north Indian Ocean, they pointed out. So less moisture was fed to the monsoon over South Asia. Moreover, the dimming suppressed the greenhouse warming over the north Indian Ocean while such warming proceeded unabated over the southern Indian Ocean. The north-south temperature gradient in the surface water of the Indian Ocean was thereby altered. That, in turn, affected monsoon circulation and rainfall. On the other hand, simulations carried out by William K.-M. Lau of NASA's Goddard Space Flight Center in the United States and his colleagues suggest that the combination of dust and soot along the foothills of the Himalayas might increase monsoon rainfall. During the pre-monsoon months of March and April, winds brought dust from the deserts of western China, Afghanistan, Pakistan and the Middle East to the northern and southern slopes of the Tibetan plateau. The dust particles, along with the copious amounts of soot produced in northern India would absorb sunlight and heat the air over the slopes. As the hot air rose, it drew in moisture-laden air from the oceans. The result could be an earlier onset of the monsoon and a longer rainy season, they observed in a paper published in *Climate Dynamics* in 2006. If soot coated the larger dust particles, the heating of the atmosphere would increase dramatically, said Dr. Lau at a monsoon conference in Bangalore in 2007. Also, while there could be more rain over northern India, there might be less rain in the south. However, all these results needed to be validated with many more model studies as well as with actual observation, he added.

In order to understand the climate impact of human-generated aerosols, it was also necessary to examine the role of natural aerosols, according to Dr. Srinivasan. When the effect of carbon dioxide on the climate was studied, the levels of the gas generated naturally as well as by humans were both taken into account. The same approach must be followed for aerosols too, he said.

On a global scale, natural aerosols were several times more abundant than major human-generated aerosols, according to S.K. Satheesh of the Centre for Atmospheric and Oceanic Sciences at Indian Institute of Science and K. Krishna Moorthy of the Indian Space Research Organisation's Thiruvananthapuram-based Space Physics Laboratory in a review paper published in the journal *Atmospheric Environment* in 2005.

The abundance of natural aerosols, such as soil dust, was increasing as a result of deforestation and other human activities. The presence of natural aerosols could influence the impact that human-generated aerosols had on the climate and it was difficult to separate the impact produced by the two types of particles when they were in a mixed state, they pointed out. The strongest natural aerosol production was that of sea salt, according to Dr. Satheesh and Dr. Krishna Moorthy. It was estimated that one to 10 billion tonnes of sea-salt aerosols were produced each year, making up 30 - 75 per cent of all natural aerosols. The sea salt particles had a strong cooling effect on the climate. In fact, some studies indicated that the quantities of sea salt whipped up by high winds could have a cooling effect that would match the heating produced by a projected doubling of carbon dioxide levels.

Chemical analysis of aerosols over the tropical Indian Ocean that surrounded the subcontinent showed that natural aerosols were more abundant than human-generated ones for over half the year. Dust from the Arabian peninsula and sea salt were the major natural aerosols that were present. A study published by Dr. Lau and Kyu-Myong Kim in 2007 showed how dust can drastically affect the climate. Just a year after Hurricane Katrina wrought havoc in southern United States, the initial signs for the 2006 hurricane season were ominous. It looked as if 2006 too would see above-average hurricane activity. But that year saw only the usual number of hurricanes and none

Natural aerosols are far more abundant compared to those generated by human activity. PHOTO: PTI

even came close to threatening the U.S mainland. Dr. Lau and Dr. Kim attribute this to an abrupt drop in the temperature of the waters of the Atlantic Ocean at the start of the hurricane season. This sudden cooling of the Atlantic had come about because of a considerable increase in the amount of dust carried by winds from the Sahara desert that year, they believe. There is not much that can be done to control the generation of natural aerosols. But that is certainly not the case with human-produced ones. Providing households with energy-efficient and smoke-free cookers would, for instance, help reduce the amount of soot that enters the atmosphere, point out Dr. Ramanathan and Dr. Carmichael.

Likewise, small industries could be given technology to reduce emissions from the burning of coal. Since aerosols have only a short lifespan, such actions could quickly mitigate global warming trends and also have a positive impact on human health. But reduction in soot levels can only help delay and not prevent unprecedented climate changes due to [carbon dioxide] emissions, they emphasised.

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