

# The even darker side of brown clouds

AMANDA LEIGH HAAG

Atmospheric aerosols compete with carbon dioxide as an agent of warming.

In the charge against global warming, carbon dioxide has long held sway as public enemy number one. But now, less-recognized molecules are entering the fray as significant agents of global warming. Aerosols emitted from smokestacks, exhaust pipes and domestic cooking fires consist of substances such as sulphates and nitrates that scatter light and have a local cooling effect; they also contain black carbon — or soot — a byproduct of incomplete combustion, which absorbs light.

Scientists modelled the behaviour of the cooling particles years ago, but so few direct measurements have been made of the heat-absorbing effects of black carbon that, even now, models do not adequately represent their influence. The most recent assessment of the Intergovernmental Panel on Climate Change<sup>1</sup> reported that the total contribution of aerosols to climate warming since the onset of the industrial era was about 20% of that caused by greenhouse gases. As much as half of the recent warming trend attributed to CO<sub>2</sub> and other greenhouse gases is thought<sup>1</sup> to have been cancelled out by cooling from aerosols. But new observations show that in some regions black carbon is as culpable as CO<sub>2</sub> for the warming, and in some cases, has a greater effect.

In a study published recently in *Nature*<sup>2</sup>, Veerabhadran Ramanathan, an atmospheric scientist at the Scripps Institution of Oceanography in La Jolla, California, and colleagues, report that aerosols locked up in brown clouds over Asia are significant contributors to regional warming. ‘Atmospheric brown clouds’, which appear as a dark haze on the horizon, are formed from a cocktail of warming and cooling aerosols in the atmosphere. Once thought to be a local phenomenon, brown clouds that originate in urban centres from Los Angeles to Beijing are now known to travel thousands of kilometres, transported



© NASA/GODDARD SPACE FLIGHT CENTER/JEFF SCHWALTZ

‘Atmospheric brown clouds’, which appear as a dark haze on the horizon, are formed from a cocktail of warming and cooling aerosols in the atmosphere.

by air currents and high winds. “Brown clouds from the United States cover the Atlantic, the European brown cloud goes over central Asia, and China’s brown cloud crosses the Pacific over to us,” says Ramanathan. “We are each a back yard to someone else, and we’re polluting every other person’s back yard.”

**“The underlying message is that CO<sub>2</sub> is driving these climate changes. The aerosols in some places are intensifying that change, and in other places they are masking that change. We are just slowly unravelling these brown-cloud effects.”**

V. Ramanathan

## CLIMATE CULPRITS

Ramanathan and colleagues chose the Indian Ocean as the ‘back yard’ in which to study the warming effects of black carbon. In the winter and spring, heavily polluted air masses are transported over the Indian Ocean from central Asia, where the majority of black carbon is from cooking fires. Brown-cloud solar absorption usually takes place in the lower 3 km of the atmosphere and heats the atmosphere up to 5 km high. The scientists measured lower atmospheric heating in a 3-km-thick cloud layer over the Indian Ocean in March 2006 using 18 missions of three unmanned aerial vehicles (UAVs) launched from the island of Hanimaadhoo in the Maldives. Equipped with instruments to measure aerosol-particle concentrations and solar radiation, the UAVs were flown in a stacked manner, separated in height

by only tens of metres and in time by less than ten seconds, making it possible to measure atmospheric heating rates directly. They found that the pollution cloud was responsible for 50% of the lower atmospheric heating, with the rest attributable to greenhouse gases.

Taking a longer-term perspective using climate-model simulations, Ramanathan's team estimated warming in the lower atmosphere from both aerosols and greenhouse gases at about 0.25 °C a decade, sufficient to account for the retreat of the Himalayan glaciers. Because the Himalayan glaciers lie at such high altitudes, they are directly affected by the atmospheric warming effect from brown clouds, yet can also be influenced by soot deposition. Black carbon from aerosols eventually condenses out of the atmosphere and settles on ice and snow, significantly increasing the amount of sunlight that is absorbed. Researchers have recently found that the influence of black carbon on temperature and the melting of snow is three times greater than that of CO<sub>2</sub> in Arctic regions<sup>3</sup>.

**“We will need to both slow CO<sub>2</sub> emissions and make a strong effort to reduce other sources of global warming to avoid highly undesirable climate effects.”**

James Hansen

In contrast to greenhouse gases, which are evenly mixed and behave rather uniformly on a global scale, aerosols have different regional characteristics. Although solar absorption owing to black carbon is ubiquitous wherever black carbon is found, Ramanathan says: “The actual magnitude of the warming trend strongly depends on the concentration of brown clouds and the meteorology, both of which vary regionally.” For instance, during the spring and winter time in Asia, aerosols can have a cooling effect on the ground, while at the same time having a warming effect in the atmosphere, Ramanathan explains. “The underlying message is that CO<sub>2</sub> is driving these climate changes. The aerosols in some places are intensifying that change, and in other places they are masking that change,” Ramanathan says. “We are just slowly unravelling these brown-cloud effects.”



Combined warming from aerosols and greenhouse gases may account for the observed retreat of the Himalayan glaciers.

#### ABOVE AND BEYOND

“These are really important new measurements that are specifically aimed at quantifying the magnitude of this effect, with the caveat that it is specific to this region and this particular arrangement of land, ocean and mountain,” says Jerry Meehl, a senior climate scientist at the National Center for Atmospheric Research in Boulder, Colorado, who was not involved in the study. James Hansen, a climatologist with NASA's Goddard Institute for Space Studies in New York, who previously reported a similar warming effect of black carbon deposited directly onto snow and ice<sup>4</sup>, notes that industrial pollution from Asia is likely to be having an increased warming effect on the Himalayan glaciers owing to a decrease in the ice albedo (its ability to reflect light), which increases solar absorption and speeds melting. This effect may make a significant contribution beyond the atmospheric warming measured by Ramanathan and colleagues. “Given that we are finding such depositions as far away as the Arctic, it is undoubtedly even more important close to India and China,” Hansen says.

Many questions remain, and further observations are needed before scientists can reliably predict to what degree black carbon will contribute to future warming. Yet determining how to regulate black carbon may prove easier than curbing greenhouse gases. Unlike greenhouse gases, which stay in the atmosphere for hundreds of years, “black carbon's lifetime is only a few weeks to a month, so if you cut down the emissions the effect would be felt almost immediately,” says Ramanathan. But curbing either source of emission alone won't be enough. According to Hansen “It appears that we will need to both slow CO<sub>2</sub> emissions and make a strong effort to reduce other sources of global warming to avoid highly undesirable climate effects.”

*Amanda Leigh Haag is a freelance science writer based in Denver, Colorado.*

#### REFERENCES

1. Forster, P. *et al.* in *Climate Change 2007: The Physical Science Basis* 131–217 (Fourth Assessment Report of the Intergovernmental Panel on Climate Change).
2. Ramanathan, V. *et al.* *Nature* **448**, 575–578 (2007).
3. Flanner, M. *et al.* *J. Geophys. Res.* **112**, doi:10.1029/2006JD008003 (2007).
4. Hansen, J. *et al.* *J. Geophys. Res.* **110**, doi: 10.1029/2005JD005776 (2005).