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FOR MOUNTAINS AND PEOPLE

Black Carbon in the Hindu Kush-Himalayan Region

INFORMATION SHEET #2/11

People in the Hindu Kush-Himalayan region are being affected by many factors from globalisation to a changing climate. Climate change is emerging as a major driver for changes in the region's weather, snow cover, water availability, agriculture, ecosystems, infrastructure vulnerability, and economic potential, all of which affect people's lives and livelihoods. Whereas climate change on a global scale is driven largely by greenhouse gases, with a smaller contribution from absorbing and scattering aerosols in the atmosphere, in the Hindu Kush-Himalayan region there are indications that absorbing aerosols containing large amounts of black carbon are playing a significant, perhaps even dominant, role in changing the region's climate. This information sheet provides a brief description of what black carbon is and where it comes from, as well as of its impacts on the Hindu Kush-Himalayan region.

Climate change in the Himalayas

In recent decades, rising temperatures; changes in the timing, location and amount of rain, snowfall, and cloud cover; retreating glaciers; and reduced snow cover all indicate changes in the climate of the Hindu Kush-Himalayan region. Climate change is starting to have profound impacts on the lives and livelihoods of people living within and downstream of the mountains as it affects water availability, agriculture, ecosystems, infrastructure, and disaster vulnerability. The region is particularly vulnerable to changes in the timing, amount, and spatial distribution of monsoon rainfall, and in the availability of snow- and ice-fed river water during the dry season. Temperatures appear to be rising particularly rapidly at higher elevations, with a consequent decline in glaciers and snow fields.

Part of the change in the Hindu Kush-Himalayan region can be attributed to the global increase in atmospheric concentrations of long-lived greenhouse gases, which warm the Earth's surface by absorbing some of the earth's outgoing infrared radiation and radiating it back down to the surface. However, recent studies point to the fact that a large part of the observed change in the region's climate has been driven by the presence in the atmosphere of aerosols containing black carbon.

Haze above the Pokhara valley (left) and over Kathmandu (right)

What is black carbon?

Black carbon is a product of incomplete combustion (burning that gives off smoke). It is the main constituent of soot. Fine particles of black carbon can be suspended in the atmosphere in the form of an aerosol. Emission inventories and analyses of aerosol samples indicate that more than half of the black carbon emitted in South Asia comes from burning of biofuels – mainly wood and mostly from cooking fires. Other large sources include burning of coal (for example in thermal power plants and brick kilns), exhaust from diesel vehicles, burning of waste, and forest fires. Once the black carbon particles have risen into the air, they can be transported over long distances by prevailing winds. They are slowly removed from the atmosphere (in days to weeks) either by slow settling and deposition onto surfaces, or in rain drops and snowflakes. We see black carbon aerosols in the form of a dark haze – the 'atmospheric brown cloud' visible in satellite images. We see the deposited particles as black dust that settles inside and outside, and in the sooty marks left by 'dirty' rain.

Black carbon in the Hindu Kush-Himalayan region

The Himalayan mountains and southern parts of the Tibetan Plateau receive most of their black carbon from the South Asian plains, but they do occasionally get black carbon from as far away as Africa (from biomass burning) and the Middle East (from fires of burning fossil fuel). Further north, the eastern and northern parts of the Tibetan Plateau receive much of their black carbon from central China, while the Karakoram region receives a large contribution from the Middle East, Europe, and North Africa.

How does black carbon affect the climate?

There are two main ways that black carbon can affect the climate in the mountains. First, when black carbon is deposited onto snow or ice, it darkens the surface, which means more sunlight is absorbed and the surface warms more. Black carbon deposited onto glaciers in China has been found to darken them by up to 5 %, accelerating their melting. Black carbon can also make snowfields melt quicker, exposing darker surfaces underneath to sunlight sooner, and allowing them to heat up even faster. It is possible that black carbon can accelerate the spring melting of snow on the Tibetan Plateau, which will warm up the Plateau earlier in the year, changing atmospheric circulation patterns and affecting the monsoon patterns.

The second way that black carbon affects climate in the region is by absorbing sunlight while it is suspended in the atmosphere. This warms the air higher up, while depriving the surface underneath of sunlight. The result can be cooling of valleys and lowland areas, contributing to the increased build up of fog observed in river valleys and over the northern Ganges Plains, as well as a lowering of winter temperatures. The reduced sunlight also affects crop and other biomass yields. The effect in high mountain areas is different; the air heated up by the atmospheric black carbon is in contact with the mountains, warming them. This is the likely explanation for the more rapid increase in temperatures at higher altitudes in recent decades.

As a result of these effects, black carbon is likely to be responsible for a considerable part (around 30% according to some recent estimates) of the glacial retreat that has been observed in much of the Hindu Kush-Himalayan region.

Aerosols

Aerosols are fine solid or liquid-covered solid particles suspended in air. Atmospheric aerosols can absorb or scatter some of the incoming solar radiation. Highly reflective aerosols, such as those composed mainly of sulphate, scatter back to space solar radiation that would otherwise reach the earth's surface and have a cooling effect. In contrast, dark coloured aerosols, like those that contain a high fraction of black carbon, can absorb solar radiation: thus they heat up the atmosphere, while cooling and darkening the earth's surface below. Other aerosols, such as fine windblown dust, have intermediate effects, reflecting part of the sunlight, and absorbing part of it. Black carbon is of particular concern because it is emitted in large quantities downwind of the Hindu Kush-Himalayan region, and because it is already showing a large climate impact.

Effects on the monsoon

There has been significant debate among scientists in recent years about how black carbon would affect the monsoon circulation in the Hindu Kush-Himalayan region. Overall, studies suggest that black carbon aerosols may substantially alter precipitation patterns, and affect cloudiness and temperature.

A number of specific ideas have been put forward, but further investigation will be needed to verify them. For example, by cooling the land surface, black carbon might reduce the land-sea thermal gradient and reduce the strength of the circulation. On the other hand warming up of the air over the Himalayan foothills might drive stronger convection (the 'elevated heat pump hypothesis').

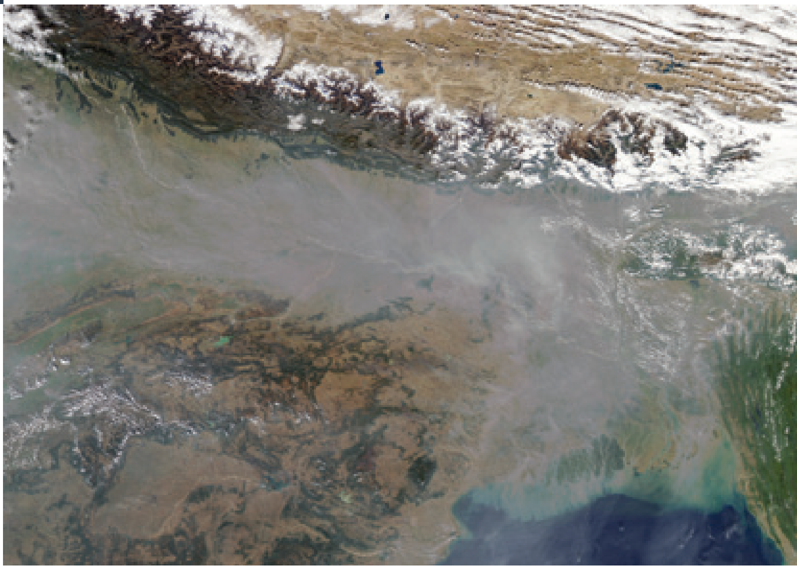
Black carbon over the ocean might cool the ocean surface, reducing evaporation and thus the amount of water available to the monsoon.

Black carbon might also suppress rainfall by seeding a larger number of smaller water droplets, leading to clouds that are less likely to rain out. On the other hand, clouds with water droplets that have been unable to rain out might store the water longer and eventually create larger precipitation events, with more intense downpours. Also, clouds with smaller droplets become whiter and more reflective, adding to the surface cooling.

Unfortunately, there is still very little field data available from the region which can be used to test these hypotheses, and it is even more difficult to understand how the different processes might interact with each other.

Other effects of black carbon aerosols

The increased heating of the upper atmosphere and cooling of the surface can have other effects. First, it suppresses atmospheric convection. This can affect air quality and human health by reducing ventilation of pollutants away from the surface, leading to the formation of a visible layer of trapped pollutants with a high proportion of black carbon over cities and in valleys. The surface cooling can increase the need for heating, which is often done with fires that burn dirty fuels and emit more black carbon. Black carbon itself can have a direct impact on health: inhaled black carbon has a greater impact on the lungs than the average aerosol. Black carbon contributes significantly to haze which obscures visibility. This impacts both the livelihoods of people who depend on mountain viewing tourists, and aviation safety.



NASA Modis image from 14 December 2009 showing haze over the Ganges basin bounded by the Himalayan mountains to the north

Mitigating black carbon

Unlike greenhouse gases, black carbon is very short-lived in the atmosphere, disappearing within days to weeks after the sources are shut down. Reducing black carbon aerosols would both reduce the climate impact, and benefit human health. Ways to reduce black carbon emissions include using alternative fuels for cooking, and/or stoves that burn more cleanly; reducing emissions from smokestacks, from industries using coal, and from vehicles, especially diesel-powered; as well as reducing open burning of waste through improved waste disposal procedures.

Machhapuchchhre in December 1973 (left) and January 2011 (right) showing loss of snow and glacier cover on the south face

ICIMOD and black carbon

ICIMOD is concerned with all aspects of climate change and its impacts on the people of the Himalayan region, with a special focus on likely future scenarios, existing and potential adaptation strategies, local knowledge relevant for future adaptation, and possibilities for mitigation.

The Centre has been contributing to ongoing research into the atmospheric brown cloud for some years. Now recognition of the extensive role that black carbon and other climate forces can play in climate change, and the potential for mitigation, mean that scientific information is urgently needed to feed into policy and decision making related to black carbon.

More comprehensive and better quality data is needed on both the source and the impacts of black carbon in the region in order to be able to predict future climate change. The results of regionally conducted research need to be shared widely, and the knowledge gaps highlighted. Equally important, the actions that could be promoted to mitigate the impacts of black carbon will have clear impacts at the level of crops, human health, and livelihoods, and will require actions at both the local and policy levels. These multiple dimensions need to be taken into account in ongoing and planned research activities.

Among others, ICIMOD is considering establishing a regional cell for gathering, packaging, and disseminating research and knowledge on black carbon, including impacts and solutions, to help address these issues and contribute to improved planning and implementation of adaptation and mitigation programmes. Black carbon is a transboundary issue and needs transboundary solutions. This makes it all the more necessary and urgent for ICIMOD to be involved in correctly assessing the problem and in contributing to finding solutions for reducing black carbon and other short-lived aerosols, since these solutions can have immediate benefits for the people of the region.

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Photos: pp 1, 2, 4 (top right, and bottom) – Arnico Panday
p 4 (top left) – Fritz Berger
p 4 (bottom right) – Min Bajracharya

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