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Arctic Climate Effects of Black Carbon

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Oral Testimony

Thank you Chairman Waxman, Mr. Davis, and members and staff of the committee for hearing my testimony regarding the effects of black carbon (BC) on Arctic climate.

The Arctic is warming about twice as rapidly as the rest of Earth. Although long-lived man-made greenhouse gases (GHGs) are the dominant cause of Earth's recent warming, short-lived black carbon particles explain a significant fraction of the observed Arctic warming.

My colleagues have described what BC is, where it comes from, and how effectively BC reductions could slow down near-term global warming. The four points most relevant to black carbon in the Arctic are:

1. Most Arctic BC comes from fuel-combustion not from open fires.
2. BC appears to warm the Arctic more than any other agent except CO_2.
3. Arctic climate is very sensitive to the surface warming that BC causes.
4. Reducing Arctic BC now will cool the planet more than a delayed reduction.

We know that economic and technological factors affect Arctic BC concentrations. From 1880–1950, industrial emissions increased BC concentrations in Greenland snow seven-fold relative to pre-industrial levels. BC concentrations in Greenland have been lower since about 1950, likely due to North American shifts in combustion fuels and technology combined with wildfire suppression. BC decreased in some Arctic regions in the late 1980s and early 1990s during the decline of industrial activity in the former Soviet Union. Late 20th century increases in Greenland BC may be linked to increased coal combustion in the rapidly expanding Asian economies.

There are three reasons why black carbon warms the Arctic more than any agent except CO_2. First, BC absorbs sunlight and warms the Arctic atmosphere by approximately the same amount as human-injected CO_2 in spring and summer, when snow and ice are most vulnerable to melting. Second, BC also warms the Arctic, including in winter, by thickening low-level clouds that then trap more of Earth's emitted heat.

Finally, black carbon warms the Arctic after it lands on the surface. Surface BC is an impurity that darkens the otherwise bright Arctic snow and ice, causing them to absorb more sunlight. This "dirty snow", seen in the picture, warms and melts the Arctic surface very efficiently because the heat is trapped at the surface by the strong Arctic temperature inversions and by the insulating properties of the snow itself. Over the course of the Arctic spring, BC-contaminated snow absorbs enough extra sunlight to melt earlier—weeks earlier in some places—than clean snow.

Melting Arctic surfaces uncover the darker underlying surfaces such as tundra and ocean. These dark surfaces absorb even more sunlight, triggering a powerful climate-warming mechanism known as "ice-albedo feedback".

In the pre-industrial climate, BC was less effective than windblown dust at triggering ice-albedo warming. But man-made GHGs have not only warmed the Arctic, they have exacerbated its vulnerability to warming by other pollutants such as black carbon. As the diagram shows, darkening of snow and ice by human-injected black carbon has warmed the Arctic by about 0.5 °C since the pre-industrial era.

Warm snow is darker than cold snow so the ability of a cleaner Arctic surface to cool the planet will diminish as the Arctic warms. Snow and ice retreat also weaken black carbon's leverage over Arctic climate. Hence the diagram shows that reducing the concentration of BC now will cool the Arctic significantly more than a delayed reduction.

Nothing in climate is more aptly described as a "tipping point" than the 0 °C boundary that separates frozen from liquid water—the bright, reflective snow and ice from the dark, heat-absorbing ocean. Arctic snow, glaciers, and sea-ice are on average about 1.5 °C warmer than in the pre-industrial era. This may not sound like much, but each above-freezing day causes more melt which amplifies the strong Arctic warming effects. GHG and BC-induced warming are inexorably pushing more of the Arctic, earlier in the year, towards its 0 °C tipping point.

In summary, because of its short lifetime and strong effects, reducing Arctic black carbon concentrations sooner rather than later is the most efficient way that we know of to retard Arctic warming. Thank you for your attention.

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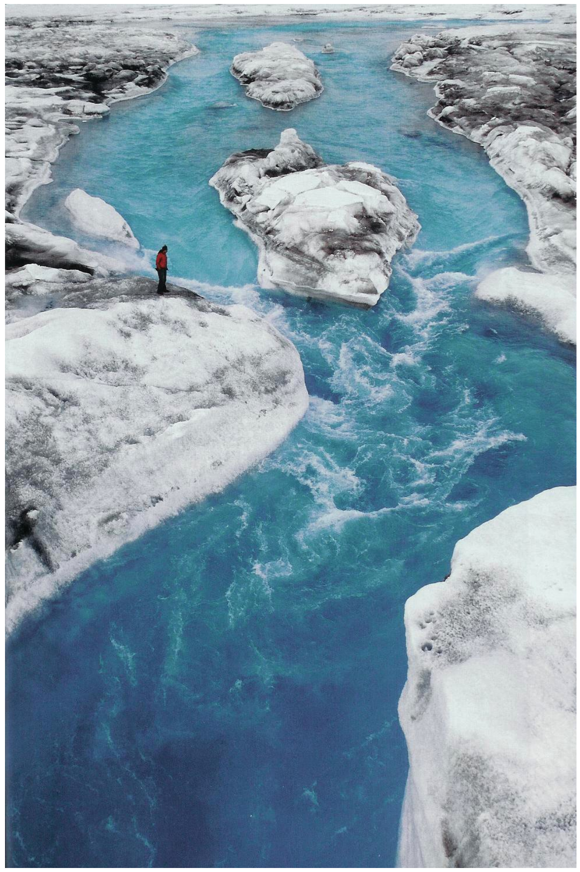

Figure 1: Greenland meltwater, surrounded by dirty snow, draining *into* the ice sheet, lubricating it. (Photo: James Balog, National Geographic)

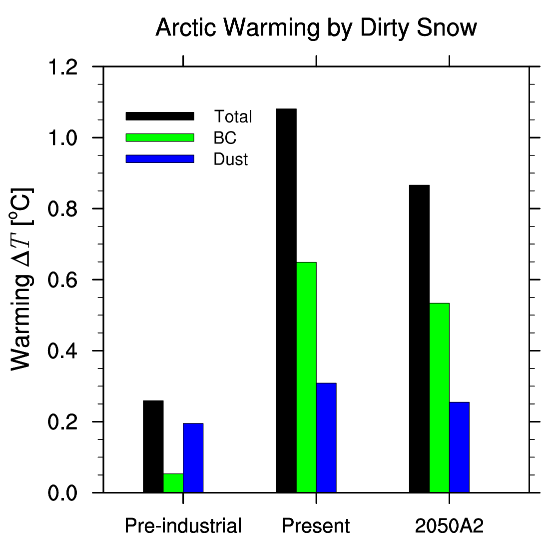

Figure 2: Predicted Arctic warming [°C] due to snow and ice contamination by black carbon (BC), mineral dust, and both (Total) during Pre-Industrial, Present Day, and year 2050 (IPCC A2) climates. Increased warming from Pre-industrial to Present is due to human-injected black carbon. Reduction from Present to 2050 caused by snow and ice retreat.